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MUNICIPAL AFFAIRS

Innovative Housing Grants Program

FEASIBILITY OF ENERGY RECOVERY FROM WASTE FOR ALBERTA

March, 1987

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of Alberta Municipal Affairs. The Innovative Housing Grants Progaram is intended to encourage and assist housing research and development which will reduce housing costs, improve the quality and performance of dwelling units and subdivisions, or increase the long term viability and competitiveness of Alberta's housing industry.

The program offers assistance to builders, developers, consulting firms, professionals, industry groups, building products manufacturers, municipal governments, educational institutions, non-profit groups and individuals. At this time, priority areas for investigation include building design, construction technology, residential building product development or improvement and information technology.

As the type of project and level of resources vary from applicant to applicant, the resulting documents are also varied. Comments and suggestions on this report are welcome. Please send comments or requests for further information to:

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EXECUTIVE SUMMARY

As waste incineration is practiced throughout the developed world, the technical feasibility of this concept is not really in question. What is of concern to municipal managers in Alberta are the direct and indirect costs and benefits of this method of municipal waste disposal. Municipalities increasingly face the dilemma of what to do with the never ending flow of domestic and industrial non-hazardous refuse. This study examines the economic ramifications of waste incineration with and without energy recovery in facilities of up to 100 tons per day, and only as such concepts relate to Alberta.

Using the most current cost data and energy costs available for Alberta, a financial model was created to analyze key economic factors affecting waste-to-energy systems which were found to be interest rates, the size of the waste stream, the type of energy to be generated, and prices of equivalent energy. The main study conclusions are listed below.

1. The primary purpose of waste incineration is to facilitate waste disposal by means of volume reduction.

2. Environmental effects can be kept within existing operational standards as defined by Alberta Environment.

3. Energy can be recovered from the incinerated garbage. Generating hot water or steam which is used as a source of heat is the most common method. Energy in the form of electricity from small incinerators does not appear to be common.

4. The market for recaptured energy is questionable because the recaptured energy costs too much.

5. The concept of district heating for small towns, or subdivisions of large cities, is not practical for Alberta at this time. The best prospect is for the integration of an energy recovery incinerator with one large commercial/industrial user of the energy.

6. The addition of energy recovery equipment can be shown to reduce the net cost per ton of waste disposal, if there is a customer for the energy.

7. To build an incineration facility without energy recovery can be justified only if:

    a. its estimated waste disposal cost per ton is

approximately equal to that of other methods;

b. there are constraints on other methods of disposal which renders them unacceptable at any price; and/or

c. there is the potential to retrofit the incinerator when economic conditions indicate that the sale of heat and/or electricity reduce the net per ton cost of waste incineration.

Since this report presents the methods by which findings were obtained, it will allow municipal decision makers to substitute their own situation and (then) current costs for equipment and energy when they are contemplating waste-to-energy systems as a means of refuse disposal.

1.0 INTRODUCTION

In the Province of Alberta, as in every other area of the world, the population produces an abundance of waste. This waste goes by many different names, including garbage, refuse, and trash. But whatever name is used, the necessity of removing and dealing with it remains the same. While archaeologists of the future will love studying twentieth century man's (and woman's) production, removal, utilization, and disposition of their undesired leftovers, governments of today must deal with the reality and expense of disposing of it.

While garbage is not a renewable commodity in the usual sense, it is most certainly a recurring commodity. Every municipality in the Province of Alberta has a "garbage problem" that must be dealt with in some manner. One town, Wainwright, is attempting to solve this problem using controlled incineration, but without energy recovery. This study will concern itself with the likely implications, including the expected costs and benefits of implementing a waste-to-energy system in Alberta municipalities using controlled incineration.

It was the intent of this study to examine the feasibility of integrating an energy recovery waste incineration with a district heating system for subdivision commercial and/or industrial buildings. However, subsequent detailed examination of the large energy generation potential of an incinerator compared with the relatively small and fragmented demands of a typical "town center" rendered this concept impractical, as will be shown later.

The study will limit itself to garbage incineration systems disposing of up to 100 tons of garbage per day. Actual daily tonnages examined will be a function of several factors, among them the population density of the area in question, per capita refuse generation, and the nature of the end user for the energy recovered. Only two Alberta cities, Edmonton and Calgary, generate refuse in an amount that would justify an incinerator with a capacity greater that 100 tons per day.

Of primary importance is the gathering of current capital and operational cost data from existing waste-to-energy systems, preferably in North America, and relating those data to known waste production information and energy requirements of various municipalities in Alberta.

Because of the need for recent data, the best sources of information were found to be current periodicals. As well, a questionnaire was sent to known operating North American

waste incineration facilities. Alberta Energy and Natural Resources Energy Conservation Branch has provided extensive data on energy requirements of typical municipal buildings.

The first part of this report contains the results of a literature search detailing the general subject of waste incineration and energy recovery. This is followed by chapters dealing with environmental aspects and a survey of current waste-to-energy systems operating in North America. The remainder of the report documents costs, revenues, and factors in the economy that have an impact on the future of waste incineration and energy recovery.

It is hoped that the findings of this report will provide municipal decision makers with information to help determine the value of waste-to-energy systems. This report explains the costs and benefits of implementing these types of systems. It attempts to answer the question, "Can waste disposal with energy recovery be practical for Alberta?"

2.0 WHAT IS WASTE INCINERATION?

2.1 INTRODUCTION

A wealth of material exists on the general subject of waste removal, waste handling, and waste disposal. However, this is not the case for waste disposal by incineration, particularly on a smaller scale. The reference sources address themselves to the very large facilities that handle the waste from large urban centers. For example, New York City produces, and disposes of, over 22,000 tons of refuse per day, at this time by landfill, but formerly by incineration, a volume difficult to comprehend. Relatively little regarding the incineration of smaller tonnages of refuse has been found.

The literature can be divided into four categories as follow:

1. Engineering text books.
2. Current pamphlets and theses.
3. Articles from periodicals.
4. Manufacturer's product information.

The literature was reviewed to provide a better understanding of the salient issues and current state-of-the-art of municipal solid waste incineration, with practical energy recovery.

Given the volumes of refuse with which the study was concerned, periodicals have proven to be a better source of material than the text books. Therefore, two bibliography lists appear, in order to separate periodicals from other source material. Many text book sources are not included as they are repetitive.

2.2 WASTE INCINERATION TYPES AND PROCESSES

Not surprisingly, there are numerous text books on the subject of municipal solid waste incineration with energy recovery. By their very nature they are often detailed, comprehensive, and technical for the average reader. Their audiences are the civil, mechanical, and environmental engineering students and practitioners.

Only Incineration Systems by Calvin R. Brunner is discussed in detail here. The most current text appears to be the most comprehensive.

Brunner uses the commonly accepted classification of various wastes as decreed by the Incinerator Institute of America in 1968. This report concerns itself with Type 2 refuse, typical of municipal solid waste. Type 2 refuse is defined

as 50% rubbish and 50% garbage which has a moisture content of 50% and a BTU value of 4300 per pound, with 7% incombustible solids. While no strict distinction between rubbish and garbage exists, the literature implies that rubbish is that material in the refuse stream which, if left untended, would not prove to be offensive to one's senses, whereas the garbage content, if left untended, would decompose further leaving unpleasant and possibly pathogenic residues. However, throughout this report, the term, "garbage", is used to mean typical municipal solid waste, and is synonymous with "waste", "refuse", and "trash". Independent tests by The City of Edmonton Sanitation Department have confirmed that household refuse in Edmonton is consistent with the text book values.

There are currently three main methods of controlled waste incineration:

1. Air Curtain Incineration
   This is nothing more than open fire burning of refuse with a "curtain" of air forced over the burning mass to facilitate more efficient combustion by increasing the oxygen available to the fire, and to contain the flames and gaseous discharge. Due to health and safety hazards it is not a favored technique, and it does not lend itself to energy recovery. It is, in fact, no longer a legal technique in Alberta. For these reasons air curtain incineration will not be considered further in this study.

2. Mass Burn Incineration
   This is the large scale burning of refuse in a contained furnace. The form of mass burning of most interest is water walled incineration. Water walled incineration is large scale burning of refuse in a contained fire box that has tubes in its walls with water continuously circulating through being converted into steam, and then condensed back into water after some energy has been extracted. These systems are not unlike ordinary marine boilers. The tonnages of refuse consumed each day are almost invariably at least 1000 tons, with greater tonnages desired to increase utilization because of very high capital costs. In Canada, Montreal, Quebec City, Hamilton, and Toronto have water walled incinerators. Because of their consumption of refuse being in excess of the upper limit of the terms of reference of this study, this type of incineration will not be considered further.

3. Controlled Air Incineration
   In this process waste is burned in a low oxygen environment which produces combustible gases. These

gases are then passed into a second chamber for additional burning in an excess oxygen environment. The efficiency of the combustion process can be controlled and is a function of the temperature, the turbulence in the chamber, and the length of burn time. This process is of most interest because of its suitability for energy recovery and because its typical capacity (in tons of refuse) is in the correct range. Table # 1 lists the three methods and their typical capacities.

Table # 1
Methods of Incineration

Type	Approx.Daily Tonnage* Cap.	Cost/ton/day
Mass burning	1,000 +	$80,000 ++
Controlled air	8 - 500	To be determined
Air curtain	5 - 75	$5,000 +

* Many exceptions to these tonnage ranges occur.

Brunner also mentions pyrolysis, because this was the lead-in to controlled air incineration. Pyrolysis is the chemical breakdown of a material in a low oxygen, or oxygen free environment by the addition of an external source of heat. In this process combustible gases and materials are produced for later use. A simple example of a pyrolytic process is the manufacture of coke from coal for subsequent use in the making of steel in an open hearth furnace.

In comparing Brunner's 1984 text on pyrolysis with Weinstein and Toro's 1974 book, one finds the 1974 material anticipating pyrolysis as a successful process for treating municipal solid waste. The authors mention that a pyrolysis plant is "in its early phases of operation in the City of Baltimore." That plant and its technology failed, as did two other similar facilities in the United States. The difficulty in this process for waste treatment is the inability to maintain a waste stream of uniform material; therefore the fuel products were not uniform. Baltimore has subsequently torn down that pyrolysis facility and built a mass burn facility on the same spot.

Further, Brunner's heat conversion table is presented here in Table # 2 below. Values from this table will be used frequently throughout this report, without specifically referencing their source again.

Table # 2

Heat Conversion Table

1 BTU = 778 Foot-Pounds

1 BTU = 1055 Joules

1 BTU = 252 calories

1 BTU = 0.252 Calories

1 BTU = 0.0002931 Kilowatt-Hours

1 horsepower-hour = 2544 BTU

1 kilowatt-hour = 3412 BTU

1 Calorie = 3.968 BTU

1 Calorie = 1 kilocalorie (1000 calories)

Two important facts emerge from the literature:

1. The primary purpose of waste incineration is waste disposal, not energy generation.
2. On a capital cost basis, as a general rule in North America, landfill is cheaper than incineration as a means of waste disposal.

Brunner adds one other observation; steam is used for incinerator heat recovery more frequently than is hot water or hot air.

Three assertions appear frequently in nearly all references to controlled air incineration. These are:

1. Because of the intensity of the double chamber burning concept, rarely, if ever, is there any air pollution from the burning of refuse using this method.
2. Relatively little pre-separation of garbage is necessary.
3. The recapture of energy is seen to be an environmentally desirable means of reducing the cost of refuse disposal. It is NOT a utopian source of fuel for the future.

Finally, the literature shows that incineration of garbage

by any means accounts for less than 2 % of the disposition of refuse in the United States, with landfilling being the most widely used method.

2.3 CURRENT WASTE TREATMENT METHODS IN ALBERTA

No better current material on waste incineration exists than that produced in recent years in Alberta.

Robert B. Pritchard's 1977 Thesis, Solid Waste Management in Alberta gives a comprehensive overview of the legislation and practices in Alberta. A summary of Pritchard's work is included here to provide a history of waste disposal in Alberta.

Waste disposal in Alberta is handled in various ways, depending upon location, population density, and the facilities available. The refuse is disposed of either by processing it in some fashion, or by "stock piling" it (perhaps for the delight of future archaeologists!)

This stock piling takes three forms, which are as follow:

1. in dumps,
2. in modified landfills, or,
3. in sanitary landfills.

A dump, strictly speaking, is no longer legal in Alberta. However, there are many dumps still in existence. A few of these are still allowed because of "grandfather" clauses, and the others are too small to deal with effectively. Fortunately, Alberta's climate renders these dumps less pathogenic than similar dumps would be in other parts of the world.

A modified landfill is a dump with style; i.e. a depository with some degree of management. If a modified landfill services a population density of less than 10,000 people, in addition to having a fence, it must be compacted at least three times a year and then covered with soil. Burning, except under very special circumstances requiring a permit, is not allowed.

For modified landfills servicing population centers of between 10,000 and 20,000 people, the frequency of compaction must be increased to three times a week with soil placed over the refuse not more than seven days after the upper limit of compaction. Many other regulations govern the maintainence of modified landfill sites, but health, safety and environmental protection are the main concerns, tempered by practicality.

A sanitary landfill is the name given to waste disposal facilities that service Alberta population densities in excess of 20,000 people. Compaction must occur each day, with a corresponding frequency of soil overlay. Regulations are quite strict, but not unreasonable.

Selection of areas to locate these "dumps" is a very difficult political problem. The decision is based upon location, prevailing winds (both climatic and political), surface water, ground water, topography, transportation systems, population centers, etc. Obvious alternatives to "stock piling" refuse are the various waste treatment methods employed throughout the world. Treatment in this case means altering the composition of the waste, as opposed to merely compacting it in hydraulic presses to more efficiently stock pile it for those same future archaeologists. These methods include composting, recycling, and incineration.

In composting, refuse is shredded after first having extracted as much metal and glass as possible. Decomposition, and therefore, volume reduction, occurs when the shredded material is combined with air and certain microorganisms. The time it takes for this decomposition to take place depends on many factors, including the nature of the organic material, amount of air available, temperature, etc.

Recycling reduces the volume of garbage by extracting, for immediate reuse (e.g. glass bottles) or subsequent specialized reprossessing (e.g. aluminum cans), various components of the garbage. That which is not reuseable can then be returned to any of the other alternative waste disposal methods.

The third method of treatment for refuse, and the primary subject of this report, is incineration, i.e. burning garbage under very controlled conditions in order to achieve the greatest volume reduction possible while keeping emissions within allowable environmental standards.

Province of Alberta Order in Council #106/85, in anticipation of having the Environment Council of Alberta hold public hearings on the recycling of waste within the Province of Alberta, requested that the ECA, in addition to other terms of reference, "consider the potential and comparative economics of the generation of energy from wastes when the alternative of the creation of useful goods and services from wastes is not feasible." In compliance with this, and other terms of reference the ECA has produced some excellent pamphlets to help the public become better aware of the overall subject of waste management and

recycling.

Specifically, Calvin Webb's The Use of Municipal Waste as Fuel, John Lilley's Garbage to Gold? Issues and Opportunities; Terms of Reference and Background Information, and Brian Free's Muncipal Solid Waste; Alberta's Untapped Resource? are included as Appendicies A, B, and C, respectively.

The report resulting from the ECA hearings is entitled Rcycling of Waste in Alberta, Report and Recommendations of the Environment Council of Alberta; March, 1987, is scheduled for release later in the year.

2.4 GARBAGE INCINERATION IN OTHER COUNTRIES

Two magazines, The Management of World Wastes, and Waste Age are the primary sources for articles dealing with all aspects of waste disposal, with curiously, a few authors contributing the majority of the articles thereby limiting to some degree the objectivity and diversity of the source material. Other source material comes from irregular and infrequent articles in engineering journals.

Charles Peterson, in World Wastes, June 1985 gives a tabular picture of waste incineration and energy recovery throughout Europe and in Japan, shown in Table # 3, on page 10.

Only in Ireland, Greece, and Portugal is landfilling the sole method of disposal. In describing the situation in Japan Peterson states that within the first decade of the 21st century, Japan will have implemented incineration programs that will burn 91% of all combustible solid wastes. Further, two pilot plants for pyrolytic reduction of municipal solid waste built in the late 70's are now closed.

Pamela Shimell, in many articles in various issues of World Wastes discusses the European situation regarding waste incineration. While produced elsewhere in Europe, the use of Refuse Derived Fuel (RDF) is most popular in Great Britain and France, apparently because of the existing industries that are currently equipped to burn coal. Adaptation to burning RDF, or a combination of RDF and coal together, is not difficult or expensive.

Because of the population densities in Europe, most incinerator facilities are of the mass burn type, well in excess of 100 tons per day. Exceptions to this are Denmark, Sweden, and Switzerland, though many of the smaller facilities in Switzerland do not have energy recovery as part of the capital installations.

Table # 3
Energy Recovery and Incineration Facilities in
Japan and Western Europe
Less than 200 tons per day

Country	Energy Recovery	Incineration Only
Japan	18	183
Austria	0	1
Belgium	0	8
Denmark	38	0
Finland	1	0
France	25	44
Italy	5	12
Luxembourg	0	0
Monaco	0	0
Netherlands	1	2
Norway	13	0
Spain	1	1
Sweden	9	2
Switzerland	19	18
United Kingdom	2	0
West Germany	10	3
Western Europe	124	91
TOTAL	142	274

What is the current situation in North America, as reported in the periodicals? A Resource Recovery Activities Report, compiled by staff from the United States Conference of Mayors and Waste Age, and published in that magazine in November, 1985 summarizes, state by state, significant "major" waste to energy facilites. This report lists their capacities, costs, and products. As these data are the most current information available for North America, where energy costs are appreciably lower than in Europe and Japan, it is potentially of more value than any other information found in the literature search. This information forms the basis of the survey of existing facilities which is reported in Section 4.

2.5 INADEQUACIES EXPOSED BY THE LITERATURE SEARCH

There is much information that the literature search did not ascertain. While small scale garbage incineration was found to be a common and increasingly popular method of waste disposal, and while heat recovery is a logical adjunct to any controlled air incineration system, adequate information was not available in two key areas:

1. Feasibility of district heating as connected to a small scale system.
2. Feasibility of co-generation of electricity from a small scale system.

An important exception to #1 above is the town of Korsor, Denmark, which burns 28.3 tons of garbage per day, generates steam and pipes the steam 7.2 miles to heat 1300 dwellings. Operating cost per ton of refuse disposed of, after debt service and sale of steam, is approximately $18.70. No similar situation in North America has been found. The heat recovered from North American facilities is invariably used to provide heat to a manufacturing process, or to a very finite number of buildings, but not to what could be called a "district heating system." (Indeed, the importance of having a customer for the heat produced by a waste-to-energy system was mentioned frequently in the literature.)

Regarding #2 above, the possibility of having a small steam driven motor to generate electricity was alluded to in several references, but no data were obtained indicating its commercial viability.

In order to eliminate confusion, it must be stated that the term, "co-generation" has two meanings in the field of incineration. In most literature sources, the term has meant the recovery of heat to be used in at least two different ways. For example, garbage can be burned and the hot exhaust gases used to generate steam which is first put

through a turbine to generate electricity, and then put through a process requiring raw steam, or another system where some of its heat is extracted to heat a building or other entity. The other meaning for the term, primarily, but, not exclusively, found in European source material, is the generation of various forms of energy by burning two or more types of fuel, for example, garbage and coal. In this report, the term will be used exclusively to mean the production of two different forms of energy from the same charge in a system.

3.0 ENVIRONMENTAL IMPACT ASSESSMENT

3.1 INTRODUCTION

It can be argued that few topics in society generate more emotional response than the subject of threats to the environment, like air pollution. As recently as June 5, 1986 garbage incineration and its possible harmful effects upon the environment were the subject of an editorial in the Edmonton Journal. (See Appendix A.) Pollution Probe, a private environment "watchdog" group, found, and documented in a 1984 publication, the presence of dioxins in the environment and blamed three "outdated municipal incinerators - one in Hamilton and two in Toronto - for most of the trouble".

Given this emotional, but certainly not irrational, fear of possible harmful effects of incinerators, it is quite surprising to find that in the Province of Alberta there are a total of over 400 incinerators of various sizes burning almost every conceivable commodity from ordinary paper and wood chips to some highly pathogenic materials including diseased (and healthy) human tissue. These incinerators are located in schools, factories, office buildings, and hospitals, to name but a few places.

Other concerns about incinerators appear inconsequential when compared to the direct and immediate environmental aspects. It is only after all environmental concerns are appropriately addressed that other factors such as traffic, noise, and odor can be considered.

3.2 EMISSIONS

All incinerators within the Province of Alberta are monitored by the Standards and Approvals Division, Air Quality Branch, of Alberta Environment. Each entity wishing to construct an incinerator must first submit a proposal to this government agency before construction in order to obtain a "Permit to Construct".

Upon completion of construction the entity must subject the incinerator to various operational tests, and of course, pass those tests, in order to obtain a "License to Operate".

The Alberta Department of Environment's publication, Guidelines for Design and Operation of Refuse Incinerators in Alberta, produced in "in accordance with Part 1, Section 4 of the Clean Air Act (General) Regulations being Alberta Statute 216/75.", documents incinerator requirements.

Every major incinerator manufacturer must comply with strict emissions standards. It is, therefore, interesting to note

that these same manufacturers are prepared to, and in some cases in the United States, actually do, enter into long term (20 year and longer) contracts to operate the incinerators they design and build. These contracts include binding obligations to comply with existing emission standards at all times.

But what really are the dangers of certain emissions? The effects of acid rain are well documented, and its elimination is currently a subject of on-going discussions between Canada and the United States. Of special interest at the moment is the subject of dioxins.

The City of New York, being greatly concerned with this topic because of their planned mass burn incineration projects for the coming decade, commissioned an environmental engineering firm in New York, Fred C. Hart Associates, to study the cancer risk to those persons who would be exposed to dioxin emissions from proposed incinerator plants. The study found that continuous exposure for a 70 year period would produce "about 0.25 to 6.0 additional cases of cancer". These cases would be added to what is the normal cancer risk over 70 years, which "is 250,000 per million population". The summary of this study, as reported in Civil Engineering, April 1985 further stated that, "So tiny is the cancer risk that both (The United States) Congress' Office of Technology Assessment and the EPA (Environmental Protection Agency of the United States) have concluded that regulation of dioxin emissions from these incinerators is not indicated."

An ironic footnote to this New York study is that New York City has now come nearly full cycle. In the early 1950's nearly 90% of its garbage was incinerated by 22 incinerators, but all were later shut down when their emissions could not satisfy new EPA standards. Huge landfills on Staten Island were then used for waste disposal. Plans are now under way to build eight resource recovery plants to handle the 22,000 tons of refuse produced each day in greater New York.

3.3 TRAFFIC

The subject of traffic associated with incineration stations was dealt with at "WasteExpo", the annual meeting of the National Solid Wastes Management Association in New Orleans in early May, 1986. The topic was dismissed as a non-issue for three reasons, which are as follow:

1. Traffic flow patterns are already established for garbage collection and distribution to existing locations for waste disposal.

2. These patterns, with their current frequency of travel are accepted by the general populace now.
3. Locating a new incineration facility along current routes of garbage transfer, or at an existing disposal site, would not alter the public's current tolerance of the status quo.

Some representatives at the conference even went so far as to state that with an ideally located incinerator, traffic congestion resulting from garbage transfer could be significantly lessened because incinerators could be located closer to the source of the garbage than could a landfill site.

3.4 NOISE

Using reasoning identical to that which concluded that traffic need not be, and indeed, isn't, a problem in the siting of an incinerator, manufacturers have stated that no components of a modular incinerator present a noise level higher than other waste disposal methods. As all municipal incinerators have enclosed tipping floors with adequate space for trucks to turn around, noise levels can be adequately dampened.

However, if a site was selected close into industrial or residential areas, the expected noise level must be compared with existing sounds from neighboring influences (a factory or a super highway, for example.) The incineration process itself is not inherently noisy.

3.5 GARBAGE STORAGE

An examination of various manufacturer's brochures found that nearly all modular and mass burn incinerators are fueled by a continuous feed system. Therefore, for efficient operation it is necessary to have some standby garbage ready for placement in the first chamber. While consistent figures for this issue were not found, it is clear that the standby amount need not exceed one or two day's collection. Information from U.S. operators revealed that the tipping floor (refuse collection area) was always enclosed, so no harmful effects due to garbage storage were acknowledged.

Upon visiting a 200 ton per day facility in Portsmouth, New Hampshire, on what was described by the plant engineer as a normal day, the estimate by that engineer was that there was about 300 tons on the tipping floor. It was close to noon; many long liner trucks had dumped their loads during the morning. At one time during a shutdown the estimated garbage on the tipping floor was 700 tons, or 3 1/2 days of

material for incineration.

In discussions with City of Edmonton sanitation personnel, it was learned that all refuse delivered to a transfer station is sent on to the landfill the same day; none stays overnight, with the only exception being a late arriving truck delayed because of breakdown. It would appear that garbage storage should be avoided, and that incinerator facilities should not pose a problem in this regard.

3.6 SUMMARY

It appears evident that the state-of-the-art in refuse incineration poses no insurmountable environmental problems.

To see that refuse incinerators can be benign, one merely has to examine Bern, Switzerland. There, garden apartments, a soccer playing field, and a Tobbler chocolate factory surround a 200 ton per day waste incinerator.

Further, at the University of New Hampshire, in Durham, a 100 ton per day waste incinerator exists on the campus and provides steam heat to the University. A poll taken there among the students found that 46% of the student body did not know that a garbage incinerator was on university property.

4.0 SURVEY OF EXISTING FACILITIES

4.1 INTRODUCTION

This section presents current data on relevant waste to energy facilities now operating in North America. In the course of the literature search, the monthly trade magazines Waste Age and World Wastes were found to be quite concerned about the general topic of resource recovery. Accordingly, a "Resource Recovery Activities Report" was found in the November 1985 isssue of Waste Age. The study, conducted jointly by personnel from that publication and the U.S. Conference of Mayors, directed its research throughout Canada and the United States.

Of the 122 energy and materials recovery facilities identified by the Waste Age research, 31 were found to merit more study here. Another eight plants were identified through other sources. These 39 facilities became the target recipients for a special questionnaire (described in Section 4.2). Not only was it hoped that these operating incinerators would provide current information on costs and revenue, but also that these sample installations could be the objects of future fact-finding visits by municipal decision makers should they wish to pursue waste to energy technology for their jurisdictions.

4.2 DESCRIPTION OF SURVEY

A survey questionnaire was drafted and edited with the cooperation of the Section Head of Operations and Facilities, Alberta Environment. This questionnaire is shown in Appendix A. The six informational criteria used in drafting the questionnaire were as follow:

1. Physical description of facilities.
2. Environmental effects.
3. Capital costs of facility.
4. Operating costs.
5. Number of employees, and their costs.
6. Revenue.

In order to encourage the respondent to fill out and return the questionnaire, the form was purposely limited to one page, and a return envelope was included with the mail out.

The questionnaire, along with a covering letter, shown in Appendix A was sent to the five Canadian and the 34 U.S. incinerator facilities with daily capacities of less than or equal to 120 tons mentioned in Section 4.1.

After two months, a follow up letter, shown in Appendix A,

with another copy of the questionnaire, was sent to those sites which had not responded to the first mailing.

4.3 ANALYSIS OF SURVEY

Of the five questionnaires sent out in Canada, there were three responses. However, one of respondents actually managed not one, but three, incinerator facilities on Vancouver Island. Therefore, there are five sets of data on Canadian incinerators, but of these, only one has energy recovery incorporated in it.

Fifteen facilities responded to the questionnaire from the United States, although three of the fifteen had either ceased operation in the interim, or had not become operational. One facility had just become operational and could respond only with capital costs. Another two were from military bases and did not have, or could not give, detailed information. The salient information from all responses from both Canada and the United States are tabulated in Appendix A. Where no data appear, the respondent failed to fill in any information.

No respondent answered all the questions on the form. Many ignored whole sections of the questionnaire. Still others gave total figures without giving breakdowns of specific costs. No clearly definable patterns were discernable from the responses, but later in this report certain figures, among others, operating costs, will be alluded to as they pertain to the topic under discussion. The information of most value in Appendix A is as follows:

1. Date Built
2. Capacity
3. Total Capital Cost
4. Cost per Ton-Day
5. Total Operating Costs
6. Operating Cost per Ton
7. Total Revenue

Data from each of these catagories will be used in subsequent chapters of this report.

4.4 CONCLUSIONS

The range of capacities (10 to 120 tons per day) of the incinerator facilities listed in Appendix A, the period of time over which different plants were built (1979 to 1985), and the uncertainty as to precisely what equipment was bought due to incomplete answers to the questionnaire make the formation of general conclusions very difficult. As utimately the purpose of this report is to help a decision

maker for a municipality better understand the whole question of waste-to-energy incineration systems, the questionnaire's true value lies in pointing out the complexity, and importance, of obtaining detailed, site specific data on facilities within a reasonable size range equivalent to a municipality's refuse problem. For example, direct contact with, or site inspection of, such facilities as Charlottetown, PEI (design capacity of 108 tons per day) or Lewisburg, TN (60 tons per day) would give immediate first-hand information on waste-to-energy plants in the appropriate size range. A municipal entity should contact waste-to-energy facilities that deal with a waste volume nearly equal to its generation in order to obtain data germane to its situation.

5.0 CAPITAL COST
5.1 INTRODUCTION

It is important to acknowledge that the primary function of refuse incineration is volume reduction of the material. This volume reduction serves one, or several, of the following goals of municipal sanitation departments:

1. Reducing the size required for a new landfill.
2. Extending the life of an existing landfill.
3. Eliminating, or reducing, possible hazardous effects of ordinary landfill sites.

At a recent conference of the National Solid Wastes Management Association, every speaker addressing the issue of energy from waste emphasized that the problem facing many large and small municipalites in North America was one of waste disposal, and in no case should waste incineration be considered primarily as a source of energy. It is primarily a disposal method. Recapturing energy from waste, while being environmentally sensible, is merely a method of getting a contribution to the capital debt service and/or to the operating costs of the "volume reduction facility".

Therefore, this chapter will deal with the typical capital costs of incineration facilities, and address the energy recovery costs separately.

5.2 A TYPICAL WASTE INCINERATION FACILITY

There are far too many variables to conclude that there is a "typical" facility. The questionnaire in Section 4 illustrated this point well. Each component has one or more alternative methods and/or pieces of equipment to perform a given task. Some alternatives are as follow:

1. Batch feeding of waste vs. continuous feeding.
2. One large incinerator vs. several smaller units to equal the expected tonnage.
3. Enclosed building vs. open sided building.
4. Architectural and landscaping aesthetics.
5. Volume of refuse.
6. Size(s) of boiler(s).

However, generalizations can be made as to the equipment required to handle waste incineration, with appropriate energy recovery for several types of use. Appendix C gives a complete list of components for several sizes of incinerators, both with and without energy recovery equipment. Because prices with this equipment would be dependent upon specific configurations, and normally be subject to tendered bids, generalizations as to cost must

also be made. Based on the best estimates available from several manufacturers, these are as follow:

1. Incineration without energy recovery, a turnkey price, excluding the cost of land:

   Cdn$30,000 - $55,000 per ton per day capacity

2. Incineration with energy recovery, a turnkey price, excluding land:

   Cdn$70,000 - $90,000 per ton per day capacity

A local example of incinerator costs without energy recapture is shown in Table # 4, on page 22.

5.3 SIZING AND CAPITAL COST OF AN INCINERATOR FACILITY

While ranges for waste facilities with and without energy recovery have been given, some representative value must be used as a basis for estimating costs for comparison against possible revenues. Since no pattern as to costs is discernible from the questionnaire results in Appendix A, figures given recently by a U.S. manufacturer who has installed many such facilities will be used. These are US $28,000 (Cdn $39,000) for an incinerator without energy recapture, and US $53,000 (Cdn $73,000) per ton per day with energy recapture, with an assumed daily tonnage of 60 tons. In addition, a 100 ton facility, the upper limit of interest in this study, will be analyzed. This facility would be viable for cities like Red Deer, Lethbridge, and, of course, Calgary and Edmonton, although a facility that size would only serve a portion of the needs of these latter two cities (See Table # 7, on page 25).

The selected numbers are not quite as arbitrary as they may first appear. As shown in Appendix A, a waste incinerator without energy recovery, costing Cdn $36,750 per ton per day, was recently built in Tumbler Ridge, B.C., and a much larger waste facility with heat recovery was built on Prince Edward Island in 1983 for Cdn $74,000 per ton per day.

In order to rationalize the selection of a 60 ton per day facility as the example to use, one must first look at waste data for Alberta. Table #5 on page 23 shows a waste analysis for Edmonton. Table #6, on page 24 shows per capita waste generation from certain landfill sites in the province. Using the net per capita waste production figure arrived at from Table # 6, on page 24, and Table # 7, on page 25, gives tonnages of waste from various population densities juxtaposed against selected cities in Alberta and their 1986 populations. An incinerator with a 60 ton per

Table # 4

Wainwright Incinerator Capital Costs To Date

Incinerator	$522,000
Building	$528,000 (1)
Sewer	$33,000
Water	$25,400
Gas	$7,700
Electricity	$2,000
Scale	$32,000
Front End Loader	$17,700
Engineering Fee	$140,416
	==========
	$1,308,216
Capital Cost/ton/day	$32,705

1. Total area = 6,982 sq.ft. (tipping area = 3,293 sq.ft.)

day capacity could be considered for handling all, or part of, the refuse from the seven largest cities in Alberta.

A 100 ton per day facility would service virtually all of the refuse theoretically producible from Red Deer or Lethbridge, and, of course, a portion of that produced by Edmonton or Calgary. Note that because of the regional landfill system administered by the Province of Alberta, the landfill servicing Red Deer, for example, might also draw refuse from the surrounding population.

As stated earlier in this report, the amount of refuse produced per day by Edmonton and Calgary, if it were to be incinerated, could be burned using either the modular (Controlled Air Incineration) or the mass burn technology. However, if all were to be incinerated, the technology used would be either mass burning of everything, or several "satellite" modular facilities.

Table # 5

City of Edmonton
Landfill Waste Analysis
Total Wastes to Landfills in 1985

	Calorific Value MMBTU/TN	Tonnes to Landfill Cloverbar	Genstar	Total	Percent
Commercial	12.87 (5839/LB)	236,461		236,461	37.8%
Residential	9.76 (4428/LB)	143,297	48,541	191,838	30.6%
Industrial		68,317		68,317	10.9%
Inerts		129,513		129,513	20.7%
Total		577,588	48,541	626,129	100.0%

	Per Tonne		Per Ton
Collection Costs	$32.70	=	$29.67
Transfer Station Costs	$9.35	=	$8.48
Landfill Site Costs	$1.05	=	$0.95
TOTAL	$43.10	=	$39.11

Note: 1.0 tonne = 1.102 tons

SOURCE: City of Edmonton; Water and Sanitation

Table # 6

Refuse Per Capita Generation Rates from Selected Alberta Landfills

Landfill Location	Year	Population	Refuse Generated Kg/day/capita	Total Per Day
Crowsnest/ Pincher	1983	14,563	2.27	33,058.0
	1984	14,563	4.57	66,552.9
Flagstaff	1984	10,485	2.20	23,067.0
	1985	10,422	2.24	23,345.3
Foothills	1983	20,268	1.40	28,375.2
	1984	20,293	1.59	32,265.9
Lamont	1983	9,103	1.26	11,469.8
	1984	9,103	1.31	11,924.9
Leduc	1983	34,081	2.07	70,547.7
	1984	34,303	2.09	71,693.3
Sturgeon	1983	19,307	1.94	37,455.6
	1984	19,521	2.03	39,627.6
Unweighted average			2.08 kgs	
			4.59 lbs	
Totals {for weighting}		216,012		449,383.1

Per Capita Refuse Production per day 4.59 lbs

Assumed percentage of inerts in waste to be 20.7% as in Edmonton (from Table # 5, on page 23)
Net Per Capita Waste Production per day 3.64 lbs

SOURCE: Alberta Environment; Waste Management Branch

Table # 7

Daily Tonnages of Refuse Produced for Various Populations
Per capita refuse production equals 3.64 pounds

Population	Representative Alberta Cities	Tons of Refuse Produced Per Day
2,000	Athabasca (1,933)	3.6
4,000	Canmore (4,058)	7.3
6,000	Lacombe (6,033)	10.9
8,000	Hinton (8,904)	14.6
10,000	Wetaskiwin (10,103)	18.2
15,000	Lloydminster (17,389)	27.3
20,000	{includes Sask.}	36.4
25,000	Grande Prairie (26,270)	45.5
30,000	Sherwood Park (29,285)	54.6
35,000	Ft. McMurray (36,810)	63.7
40,000	Medicine Hat (42,182)	72.8
45,000		81.9
50,000	Red Deer (54,192)	91.0
60,000	Lethbridge (60,310)	109.2
70,000		127.4
80,000		145.6
90,000		163.8
100,000		182.0
200,000		364.0
300,000		546.0
400,000		728.0
500,000	Edmonton (571,506)	910.0
600,000	Calgary (640,645)	1,092.0

SOURCE: Alberta Municipal Affairs; 1986 Population List

5.4 LAND AND BUILDING REQUIREMENTS

From interviews with some incinerator operators at a recent conference, all appeared to feel that two acres of land was more than adequate for most facilities. Many facilities were located on municipal owned land. Indeed, the Wainwright incinerator land was not included in its budget, but purchased separately by the provincial government; 5.51 acres at $1000 per acre. As land costs can vary depending upon location, alternative uses, etc., selecting a particular cost here would be of doubtful value.

One manufacturer suggests that the size of the building be directly proportional to the daily tonnage, with an approximate figure of 100 square feet of tipping floor per daily ton of capacity, i.e. 5,000 sq.ft. for a 50 ton per day facility. (Wainwright's tipping area is slightly greater than 82 sq. ft. per ton.) In addition to the tipping area, the equipment usually occupies an additional 40 % the tipping area. The office necessary for any size facility need be only enough for two or three staff at most, although some offices are large. Therefore, a typical 50 ton per day facility would have a building size of approximately 7,500 sq.ft.

A 200 ton per day facility in Portsmouth, New Hampshire has a building 150 feet across by 190 feet deep. Precisely half of the building contains the tipping floor, thereby providing 71.25 sq.ft. per ton tipping area. Four incinerators operating in pairs fed by front end loaders provided heat to two boilers for the generation of steam for a U.S. Air Force base. The manager stated that, on certain occasions such as maintenance shutdowns and/or excessive refuse production, the tipping floor has held in excess of 600 tons of refuse for short periods until the backlog can be incinerated. An office on the side of the incinerator building, 30 ft. by 65 ft., houses the scale readout equipment, offices, and shower and locker facilities for men and women.

The equipment area can be open sided. The only restriction is that access to the tipping area being should be somewhat enclosed to keep out scavengers, and it should have a vertical clearance of at least 20 feet to accommodate trucks in the bed-up position.

5.5 ADDITIONAL CAPITAL ITEMS

Items such as front end loaders, or any of several methods for removing ash are, alone, quite expensive, but they represent a relatively minor part of the total initial costs. Each site will have unique requirements, but, as

will subsequently be shown, their contribution to the overall economics will have relatively little effect. For example, the front end loader used at Wainwright constitutes only 1.35 % of the total capital cost, including the cost of the land.

5.6 CAPITAL COST OF ENERGY RECOVERY

The cost of adding energy recovery equipment naturally increases the capital cost of a facility. These increases must be juxtaposed against reasonable expectations for revenue. But with fossil fuel in Alberta being plentiful and, when compared to the rest of North America, very cheap, one must be careful to fairly equate the value of the energy in refuse to current energy costs.

Appendix D contains in tabular form the theoretical energy available from waste, and its subsequent realizable energy value as heat via steam, and electricity via steam or thermal expansion. These theoretical values are derived from the basic Btu content of one pound of Type 2 refuse, 4300 Btu per pound (see Section 2.2).

Tables # 8 and # 9, on pages 28 and 29, contain data showing typical buildings, their energy usage, and its cost. Table # 8 shows the relatively small energy consumption of these buildings compared to the supply capacity of a 60 ton per day incineration facility. It is apparent that the original concept of "District Heating" for a subdivision business center, community service building, and/or single and multiple family dwellings is impractical. Therefore, all future consideration as to the utilization of the energy that might be produced will be toward a single large user of energy. Table # 9 contains data for large industrial and commercial energy users more consistent with the energy production potential for 60 and 100 ton waste incinerators.

5.7 CAPITAL COST OF ELECTRICITY GENERATION

A large steam powered electrical generator is estimated to cost US$500,000, or $400 per kilowatt. One of the major suppliers and builders of waste-to-energy facilities in the United States reports that, typically, a steam turbine attached to a waste incinerator can range between US$250,000 and $750,000. Most recently, this contractor put in a 264 KW turbine for US$150,000, giving a per kilowatt price of US$564. This figure is consistent with those supplied by an Alberta manufacturer of thermal expander generators, between $500 and $600 per kilowatt. The cost of retrofitting the existing steam generating 200 ton per day incinerator in Portsmouth, NH to utilize the steam for electricity generation rather than heat is estimated to be US$600,000.

Table # 9

Energy Bus Data Base for Typical Subdivision Buildings

BUILDING TYPE	LOCATION	SQ.FT.RANGE	NO. OF AUDITS	SEARCH NO.	TOTAL ENERGY KWh	ANNUAL USEAGE GJOULE	AVERAGE ENERGY USED PER BUILDING PER DAY KWh	GJOULE	ACTUAL ENERGY COST PER KWh	PER GJOULE
COMMERCIAL	EDMONTON	0-5000	5	4	601,815	4,041	329.762	2.214	$0.0532	$2.91
COMMERCIAL	EDMONTON	5000-10000	5	5	462,058	6,667	253.188	3.653	$0.0545	$2.76
COMMERCIAL	EDMONTON	10000-15000	4	6	4,294,410	17,747	3,009.870	12.155	$0.0402	$2.61
COMMERCIAL	EDMONTON	15000-20000	7	7	2,309,850	23,180	904.051	9.072	$0.0520	$2.68
COMMERCIAL	EDMONTON	20000-25000	4	8	1,411,950	17,592	967.089	12.049	$0.0577	$2.73
RECREATION	EDMONTON	0-25000	3	10	272,680	3,953	249.005	3.610	$0.0696	$2.70
SCHOOL	EDMONTON	0-40000	4	13	691,560	14,693	473.671	10.064	$0.0485	$2.70
SCHOOL	EDMONTON	40000-80000	2	14	1,215,900	22,268	1,110.411	20.336	$0.0542	$2.99
RELIGIOUS	EDMONTON	5000-10000	3	17	33,295	2,179	30.406	1.990	$0.0770	$3.11
RELIGIOUS	EDMONTON	10000-15000	4	18	58,804	5,505	40.277	3.771	$0.0774	$2.72
RESIDENTIAL	EDMONTON	0-25000	5	21	342,470	9,137	187.655	5.007	$0.0646	$2.94
RESIDENTIAL	EDMONTON	25000-50000	5	22	981,099	24,214	537.752	13.268	$0.0602	$2.78
							AVERAGE COST		$0.0599	$2.77

SOURCE: Alberta Energy and Natural Resources
Energy Conservation Branch

TABLE # 3

Energy Bus Data Base for Large Energy Users throughout Alberta
(Based on 468 audits conducted between 1 Jan 85 and 31 Dec 86)

BUILDING TYPE	LOCATION	AVERAGE SQ.FT.	NO. OF AUDITS	SEARCH NO.	TOTAL ANNUAL ENERGY USEAGE KWh	GJOULE	AVERAGE ENERGY USE PER BUILDING/DAY KWh	GJOULE	ACTUAL ENERGY COST PER KWh	PER GJ.	WEIGHTING FACTORS PER KWh	PER GJ.
INDUSTRIAL	PROVINCE	256,792	9	1	110,461,000	1,915,300	33,825.9	585.3	$0.0054	$2.82	$0.0186	$22.77
INDUST/COMM	EDMONTON	638,000	2	2	36,900,200	336,631	50,415.2	461.1	$0.0217	$2.50	$0.1524	$5.20
INDUST/COMM	CALGARY	572,103	3	4	34,348,000	593,425	31,368.0	633.3	$0.0380	$2.56	$0.1140	$7.68
INDUSTRIAL	PROVINCE	357,158	5	5	68,379,200	3,174,120	37,468.1	1,729.2	$0.0340	$2.51	$0.1715	$12.55
INDUST/COMM	EDMONTON	1,304,255	2	7	72,741,600	800,001	101,015.9	821.9	$0.0335	$2.99	$0.3670	$5.99
INDUST/COMM	CALGARY	411,633	3	8	40,277,000	1,526,240	36,792.6	1,393.8	$0.0352	$2.33	$0.1056	$6.99
			24						WEIGHTED AVERAGE COST		$0.0350	$2.54

SOURCE: Alberta Energy and Natural Resources
Energy Conservation Branch

5.8 CONCLUSIONS

Given that all municipalites in Alberta currently have some form of waste disposal, to some degree or another, in place in their jurisdiction, each should then know the magnitude of its waste generation. Consequently, if incineration is to be considered by a municipality, determination of the required facility size is not of great difficulty.

The costs associated with that facility could be subject to great variance. The ranges of costs for components given in this chapter are based on the best available information from both manufacturers and recently built waste-to-energy facilities in North America. For subsequent analysis in this report, the following values for components will be used.

Incinerator	$39,000 per Ton per Day
Energy Recovery	$34,000 per Ton per Day
Electricity Generation	$400 per Kilowatt

While future examination may find the costs of these components to be much different, these cost changes will not alter the validity of the method of analysis used in subsequent chapters.

6.0 OPERATING COSTS
6.1 INTRODUCTION

One of the most disappointing aspects of the responses to the questionnaire described in Section 4 was the inconsistency, indeed, in some cases, the total lack of information about operating costs. One would expect to have very precise data on this subject.

This chapter will quantify and describe operating costs although the information will be less comprehensive than desired due to data collection discrepancies.

6.2 PERSONNEL COSTS

The 200 ton facility in Portsmouth employed a total of 24 people on a 24 hour, 7 day a week basis. On a given shift, there are two front end loader operators, a general cleanup and scale reader, and a foreman. During the main business day shift (8 to 4 Monday through Friday) one other person for general labor and the overall general manager are also on duty.. Two other facilities polled by telephone gave 14 personnel for a 100 ton per day plant and 7 persons for a 50 ton per day incinerator, the latter being on a 5 day per week basis of operation. These data are plotted on Graph # 1, shown on page 32. In addition, all available data from the questionnaire are also plotted, giving an indefinite pattern.

The Canadian incinerator personnel costs from the questionnaire ranged from $7.99 to $22.40 per through ton. The only incinerator with energy recovery, in Charlottetown, PEI, indicated $9.39 per ton.

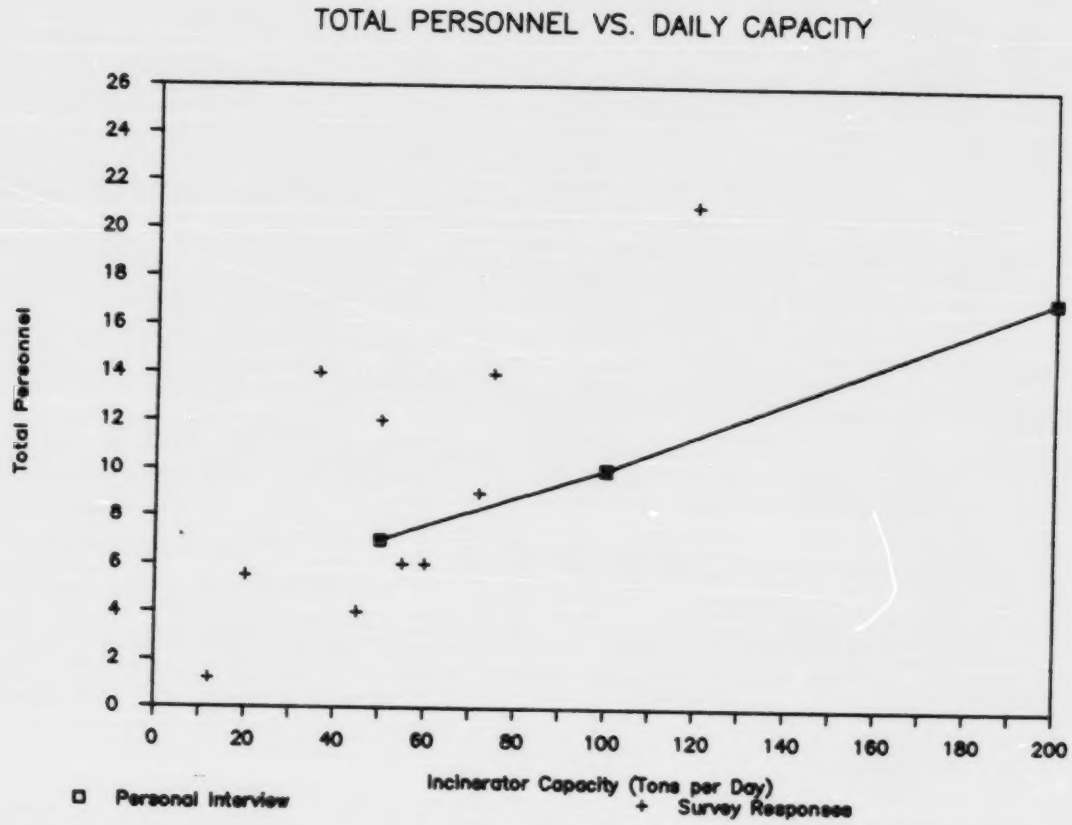
The U.S. data were equally inconsistent. Only seven facilities answered the question, and showed a range of from $4.53 to $23.39 per through ton, though three clustered around the $6.50 per ton range.

6.3 MAINTENANCE AND REPAIR COSTS

During a visit to the Portsmouth, NH incinerator the plant engineer could not emphasize strongly enough the importance of a regular, though not necessarily frequent, shutdown schedule for maintenance. Having a historical pattern for refuse flow, shutdowns are scheduled at a time when the flow was expected to be less than usual.

Given the capital cost of the incinerator equipment, the importance of regularly servicing the investment is clear. But precise figures from the questionnaire were no more easily obtainable than they were for personnel costs.

Graph # 1


TOTAL PERSONNEL VS. DAILY CAPACITY
Total Personnel
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
100
120
140
160
180
200
Incinerator Capacity (Tons per Day)
□ Personal Interview
+ Survey Responses

The two Canadian entities who responded to this question gave $6.09 and $3.43 per through ton as being the cost of maintenance. Their American counterparts' responses had a much greater range, from $1.10 to $19.02, and with no preponderance in a small range. No pattern or trend was in evidence.

6.4 UTILITY COSTS

While personnel and maintenance costs can vary greatly according to factors such as local wage rates, and the quality of management, utility costs are far more a function of the equipment selected. Manufacturers predict and specify the utility demands of their products. Of course, the unit cost of these utilities is a function of local availability.

There was less variance in the responses to the questionnaire on this subject. Charlottetown indicated $3.94 per through ton, while the other four Canadian respondents ranged from $1.25 to 1.92 per ton, though as noted earlier those four have no energy recovery facilities associated with them.

The U.S. response ranged from US$1.52 to $6.16 per ton, with the responses spread equally through that range.

6.5 DEBT SERVICING COST

This is one cost of refuse incineration that is quantifiable before an incinerator starts operation. The Wainwright incinerator has no debt service as the entire project was built using a provincial grant. The Charlottetown facility also benefited from 45 % funding via grants from both the federal and provincial governments.

In the United States, as mentioned in Section 2, many municipal incinerators have been financed using tax free bond issues, which makes the debt service approximately half the ordinary cost of capital. However, no similar financing vehicle exists in Canada at this time. For Alberta one can only estimate costs based on current interest rates. Debt servicing costs will be more fully dealt with in Chapter 7.

6.6 DEPRECIATION

Revenue Canada does not give a separate listing for incinerators per se. Therefore, that which is not itemized falls into Section 8, allowing a depreciation rate of 20% on a declining balance method. However, Regulation Schedule 2, Class 34 of the Income Tax Act of Canada does provide for an accelerated write off of 50% on energy generating equipment

using alternative sources of power. Therefore, with approval from the tax department, at least the energy recovery equipment and the generator would enjoy a faster write off.

To municipalities, depreciation is an academic subject because of their tax status. However, to a private operator the above depreciation rate would result in a very large positive cash flow in the first five years of the project that could be used to accelerate debt reduction, provide for a sinking fund for equipment replacement, or leverage into additional waste-to-energy projects.

A telling bit of information from the questionnaire is that the oldest incinerator was built in 1979. This is no doubt due to the current trend toward modular incineration and recent environmental laws which compel the industry to be relatively new. Consequently, no long term data on the useful life of modern modular incinerators are available.

6.7 CONCLUSIONS

Although the total operating costs from the facilities in Canada and the U.S. range from Cdn $4.54 to Cdn $51.04 per ton, an unweighted average for all operating costs per ton is Cdn $20.65 for the Canadian facilities which responded, and Cdn $18.03 for the American facilities. These figures exclude debt service costs, but which are known to be at least $10.00 per ton based on current interest rates.

Specific targeting of operating costs for the planned size of an incinerator in Alberta will be necessary, and these are given in Chapter 7.

7.0 POTENTIAL ECONOMIC BENEFIT

7.1 INTRODUCTION

In order to compare the costs of waste incineration for refuse disposal with those costs for waste disposal that a municipality currently spends, the economic value of incineration must be determined. The value of any waste to energy plant is measured in two ways:

1. Avoided costs:
   a. Tipping fees paid.
   b. Transportation costs.
2. Revenue:
   a. Tipping fees received.
   b. Sale of energy as heat.
   c. Sale of energy as electricity.

The avoided costs mentioned above are site specific, and not unique to waste incineration. Using Edmonton as an example, if an incinerator were located in the northwest part of the city, an immediate saving would be realized (neglecting any contractual terms) in the $5.33 per ton currently being paid to a private landfill site in that area. The city presently dumps, on an average, around 145 tons per day into the private landfill there. But the same saving through avoided costs would be realized if a city owned landfill were to be located there. Conversely, in this example, transportation costs would be nearly unaffected.

Of the revenues forthcoming from energy recovery incinerators, those from tipping fees are a function of location, and the financial structure of the municipality and how it charges for using its facility. For example, has the originator of the refuse paid for its ultimate disposition in the tax base? Does the municipality accept, and charge for, waste from other municipalities being dumped in its landfill, or its (future) incinerator? Would a tipping fee be realized only if an incinerator were to be built, or would the fee also be obtained for dumping the same refuse in a landfill sited in the same area?

Revenues from the sale of energy, however, are attributable directly to any building of an incinerator, and will constitute a major contribution to fixed costs.

7.2 TIPPING FEES

For any municipality collecting and disposing of its own refuse exclusively, with no disposal of refuse generated elsewhere, there is no tipping fee, regardless of the method of disposal (landfill or incineration) used. However, tipping fees charged by selected Canadian cities in 1984 are

shown in Table # 10, which follows:

Table # 10

Tipping Fees for Various Canadian Cities: 1984

Dollars per tonne

City	Fee
Calgary	$6.65
Edmonton (Cloverbar)	$5.00
Edmonton (Genstar)	$5.33
Regina	$5.30
Saskatoon	$4.40
Surrey	$7.95
Vancouver	$8.82
North Vancouver	$13.50
Greater Vancouver	$23.69
Victoria	$11.00
Winnipeg	$7.25

Source: Genstar Conservation Systems Ltd.,Edmonton, Alberta.

The 200 ton per day incinerator in Portsmouth, NH charges neighboring municipalities $13.50 per ton for dumping their refuse on the facility's tipping floor. As they estimate their operating costs to be $28.00 per ton, it is clear that tipping fees may not reflect actual costs. The Portsmouth facility is locked into long term contracts with its neighbors that did not take into account escalating costs.

7.3 SALE OF ENERGY AS HEAT

Appendix D contains the theoretical thermal content for various tonnages of refuse, and the current value of that heat, were it to be generated by present methods using natural gas.

Although from outward appearance the revenue from energy produced could contribute substantially to fixed capital

costs, one must be aware of the risks involved. For example, the incinerator in Prince Edward Island had a budget predicated on selling all the steam it could produce to a hospital, and spent an additional $2,000,000 to distribute the steam to the customer. After several years of operation the actual amount of steam sold was only 71.4 % of budget ($957,000 vs. $1,340,000), which, of course, altered the financial structure substantially.

Another illustration of the importance of a large, steady customer was the Burlington Northern railroad repair shop in Livingston, Montana, which formerly bought steam for heat and processing from the local incinerator. When it closed down, no alternative customer could be found, but the incinerator continued to operate because it was still the best available waste disposal facility. Appendix E, from the January, 1987 issue of World Wastes, forcefully documents the importance of not only the assurance of a steady end customer, but also the constant supply of waste.

Nowhere in Alberta is there a large steam producer that sells steam to any large user as an "arm's length transaction", although there are several who produce for internal use.

It has been found that, in nearly all cases where steam is produced for sale from a waste treatment plant, the customer for the steam is either one building requiring heat, or a manufacturing entity requiring steam for some industrial process. Clearly, one customer is desirable.

The revised Energy Bus Search showed large users of natural gas for heat to be paying $2.54 per gigajoule, a small (8%) decrease from the originally estimated $2.77 when the town center district heating concept was conceived.

7.4 SALE OF ENERGY AS ELECTRICITY

The theoretical potential for the generation of electricity is tabulated in Appendix D. Note that the calculations show that, in theory, 397 kilowatts can be generated from each ton of garbage. Actual realizable results, according to one firm who supplies, builds, and operates a number of incinerators in the U.S. northwest, states that 360 KW is more probable, and that it would be best to base estimates on only 300 KW per ton. Therefore, from the various efficiencies assumed in producing Appendix D, it would appear that safe estimates would necessitate a further reduction of about 25 percent. For example, a 100 ton per day facility could supply 1250 KW per hour. The cost of a generator to produce that electric power would be between Cdn$500,000 ($400 per KW), and Cdn$625,000 ($500 per KW). A

firm in the state of Washington recently installed a 2 megawatt generator at an incinerator for US$750,000 (Cdn $517/KW).

Appendix D then assigns a value to this electrical power generation based on current electricity costs experienced by buildings with a similar power demand. With the original small town center district heating concept, the average cost of electricity was found to be $.0599 per Kwh. However, a subsequent search of Energy Bus Data found that large users, users that may be considered potential customers for the energy from a waste incineration facility, currently pay approximately $.0350 per Kwh, a decrease from the original estimate of over 40 %. Consequently, a 100 ton per day facility could produce electricity with a current value of $1,050 per day.

While it is not dealt with here, it must be noted that generating electricity for sale in Alberta is a regulated activity. The following quotes from existing electric utility contracts provide some insight into bureaucratic restrictions that any waste-to-energy facility would have to overcome before the sale of electricity could occur:

1. From Transalta Utilities Corporation's Terms and Conditions of Electric Service, effective 1 Feb 82; *"The service supplied to the customer shall not, without the written consent of the Company, be used for standby to, parallel operation with or supplementary or auxiliary to any other source of electric supply by, or available to, the customer."*
2. From Alberta Power Ltd.'s Electric Service Regulations, effective 1 Feb 83; *"The service supplied by the Company to a customer shall not, without the written consent of the Company, be used for standby to, parallel operation with, or supplementary or auxiliary to any other source of electric supply owned by or available to the customer."*

7.5 CONCLUSIONS

The economic benefits to Alberta from any waste incinerator project would be realized in two ways:

1. Directly from the sale of energy recovered from each entity. This benefit is achievable regardless of the location of the facility, and is a function of the availability of a customer for the energy, and its price.
2. Indirectly from local, site-specific aspects of each separate project, such as transportation factors and whether or not the municipality involved would avoid current, or receive new, tipping fees.

Evaluation of these factors in light of current alternative waste disposal costs will determine the economic viabliity of any given project.

8.0 ECONOMIC ANALYSIS
8.1 INTRODUCTION

The feasibility of garbage incineration, with or without energy recovery, is not in question. The practicality of this technology for the Alberta condition can be quantified for comparison with other waste disposal techniques by municipal decision makers.

While one may question the analysis of data that have been selected from industry estimates, or responses to a questionnaire from facilities built at different times, the methods used to evaluate hypothetical incinerator configurations will be valid when precise capital and operating costs are known. Therefore, no further qualification of the data is given.

Essential to any analysis is the determination of incremental unit costs for all facets of a project.

8.2 FEASIBILITY OF GARBAGE INCINERATION

The components of incineration without energy recovery include the capital cost, the debt service, and the operating costs of a facility. The results are solely volume reduction of the refuse. Using previously documented costs a simple budget cost per ton would be as follows:

Capital Cost per Ton Incinerated	$39,000
Debt Service per Ton @ 9% rate	$9.62
Operating Costs per Ton	$20.00
Sub-total; Incineration Costs per Ton	$29.62

Therefore, even at a modest interest rate, the known cost of volume reduction of waste is nearly $30.00 per ton. The cost of ash disposal (5 to 7 % of the original volume) will be added later.

8.3 FEASIBILITY OF ENERGY RECOVERY

Continuing with an incremental analysis, the additional capital costs for energy recovery are then added, and evaluated against the expected revenue.

Additional costs of heat recovery (steam generation)

Capital Cost per Ton; Energy Recovery	$34,000
Debt Service per ton @ 9% rate	$8.38
Add: Sub-total; Incineration Costs	$29.62
Total cost/ton; steam generation; 9 % rate	$38.00

Expected revenue on a natural gas equivalent basis as extracted from Appendix D gives a theoretical revenue of $16.13 per ton of refuse.

Consequently, the net cost of waste disposal per ton with energy recovery becomes $21.87.

8.4 FEASIBILITY OF POWER GENERATION

In order to allocate a cost to the production of power, one needs to assume a reasonable tonnage per day in order to determine a generator size. As documented in Section 7.4, a 1250 KW generator for a 100 ton per day facility would cost at least $500,000. Electrical generation costs follow.

Additional costs of power generation

Capital Cost of a generator ($400/KW)	$500,000
Capital Cost per Ton	$5,000
Debt Service per Ton @ 9% rate	$1.23
Add: Total Cost of Steam Generation	$38.00
Total cost/ton; electricity; 9% rate	$39.23

Again, referring to Section 7.4, the revenue from electricity at today's cost in Alberta would be $10.50 per ton, substantially less than the value of energy as heat. The waste disposal cost per ton is then $28.73.

8.5 CONCLUSIONS

Perhaps unsurprising, waste-to-energy systems are not self-contained profit centers. Even if it were theoretically possible to extract the full potential of electricity first, and then get full theoretical heating

value from the low pressure steam and/or hot water, the economic return would still not equal the operating cost per ton plus debt service per ton of the facility.

Regarding the co-generation concept, none of the facilities contacted employed this integrated form of energy recovery. The manufacturer and operator from the state of Washington stated that he knew of no facility of under 100 tons per day that employed co-generation concepts. Even if one makes the assumption that if all the resulting energy could first be extracted as electricity, and the remaining steam and hot water, after passing through a turbine, could then be channeled through heat exchangers to extract its original theoretical thermal energy (quite impossible, of course), the resulting revenue as calculated in Sections 7.3 and 7.4, would total $26.63, still less that its combined cost of generation of $39.23 per ton.

If the theoretical electrical energy was fully extracted, it is likely that only 25 to 50 % of the theoretical thermal energy would still be usable. The resulting revenue would range between $14.53 and $18.57 per ton ($10.50 from electricity plus 25 and 50 % of $16.13 from heat), compared to the combined generation costs of $39.23 per ton. Therefore, if one could not extract at least 35 % of the theoretical heat value of the original refuse stream <u>after</u> electricity generation (the interpolated percentage of heat recovery revenue which, when added to 100 % of the electricity revenue, equals the value of the total theoretical heat recovery, specifically ($16.13 - $10.50)/ $16.13, or 34.9 %), then it is not economically sound to generate electricity at all because greater revenue can be obtained from heat generation alone.

Publicity is given to energy recovery systems because of the desirability of saving non-renewable resources and the retail cost of some forms of energy in some areas of North America. For example, the retail cost of electricity in the Portsmouth, NH area was, at last report, US$.085 per kwh. Using that figure would mean that each ton of refuse would generate electricity valued at Cdn $34.43, very close to its estimated cost of generation.

9.0 SENSITIVITY ANALYSIS
9.1 INTRODUCTION

Fundamental to any quantitative analysis regarding the effects of each variable is the importance of remembering the primary purpose of incineration; i.e. waste disposal by means of volume reduction. Therefore, any sensitivity analysis will have to determine either a net cost per ton for waste disposal, or a contribution in dollar terms to fixed costs, or, lastly, an avoided cost per ton resulting from some alternative.

While the analysis, in most cases, is predicated upon a price per ton per day, total capital costs on an entire project must be kept in mind. Accordingly, total capital costs for the major components of both a 60 ton per day incinerator, and a 100 ton per day facility, are shown in Table # 11, on page 44.

9.2 SENSITIVITY TO TRANSPORTATION

The transport of refuse from its source to the place of disposition is a significant cost of waste disposal. Private haulers in Edmonton charge approximately $.23 per ton per mile for hauling refuse. (The town of Banff spends about $20 per ton to haul its refuse to a landfill in Calgary, although this is an extreme situation.)

The inclusion of transportation costs in any study of incineration is site specific. If, for example, a site is chosen that could accommodate either a landfill or an incinerator to handle waste disposal, the cost of transportation to the site would be the same for each method of disposal. Significant savings could be realized in the situation where an incinerator, because it can be made environmentally benign, can be located much closer to population centers than can a landfill.

The placement of an incinerator at, or near to, a transfer station could add to disposal savings, by eliminating not only the $.31 per ton-mile cost that, for example, Edmonton experiences to haul compacted waste to Cloverbar, but also the entire transfer station operational costs. Furthermore, while the equipment of an incinerator will eventually have to be replaced, the land site is, in theory, good forever, thereby avoiding future transportation concerns. (Therefore, the impact of transportation on a per ton basis, given the above $29.62 basic disposal cost, while not to be ignored, is not of great importance.) A cost of about $1.00 per ton for every incremental four miles of travel is incurred, or saved.

Table # 11
Estimated Total Capital Costs
for Different Incinerator Configurations

Components	Capacity (Tons per day) 60	100
Incinerator		
Cost/ton $39,000	$2,340,000	$3,900,000
Steam Boiler		
Cost/ton $34,000	$2,040,000	$3,400,000
Generator		
$ per KW $400	$300,000	$500,000
TOTAL COSTS		
Incinerator without Energy Recovery	$2,340,000	$3,900,000
Incinerator with Heat Recovery	$4,380,000	$7,300,000
Incinerator with Electricity Generation	$4,680,000	$7,800,000

9.3 SENSITIVITY OF ASH DISPOSAL

Incineration cannot completely eliminate the need for a landfill site; rather it greatly reduces the volume of undesirable material that requires dumping. The residue left from efficient incineration is between 5 and 10 % of the original volume. (Its weight is between 40 and 60 % of the original weight because of the density of ash, and the water content from the quenching system used to suppress pollution.) In addition to ash disposal, every municipality needs to have a site for disposal of inert materials, so that the production of ash would not, by itself, necessitate creation of a special dump.

While the cost of ash disposal is, again, site specific,

discussions with some incinerator operators stressed the importance of having long term contracts for its removal, ideally on a volume basis rather than on a weight basis. Failure to insure that definite costs for ash removal were contracted for in the Portsmouth area resulted in that incinerator paying $13.00 per ton of wet ash sent to a private landfill. The resulting cost of ash removal in this case becomes between US$5.20 and $7.80 per ton of the original refuse. Although this case was an extreme situation, it serves to stress the importance and significance of ash removal for any incinerator. A private firm which operates a municipal incinerator in the state of Washington on a contract basis owns its own dump for ash disposal. (Alberta Environment is requiring the Wainwright incinerator to send its ash to a sanitary landfill.)

9.4 SENSITIVITY TO TIPPING FEES

In any municipally operated incinerator, or landfill for that matter, the inclusion of a tipping fee could be misleading. One could postulate that the municipal district must supply waste disposal service for its citizens. Therefore, whether that service is paid for by a tax base levy, or a direct tipping fee is matter of accounting. In either event, the service must be paid for in some manner.

Where the tipping fee does have a definite impact is when refuse from an outside source is disposed of by the landfill or incinerator. In another situation, an avoided cost, such as might be realized by the City of Edmonton if it were to incinerate refuse now going to the Genstar landfill, could be construed as revenue to the incinertor.

Table # 12, on page 46, shows the effect of revenue from heat juxtaposed against interest on the capital debt of a waste to energy incinerator. Table # 12 assumes no tipping fee income. Operating costs, known to be about $20.00 per ton, are ignored in this analysis.

Note that using current equivalent energy costs, as derived from Appendix D, not enough revenue is generated to service the debt, even at the lowest assumed interest rate. However, if all the refuse burned were considered to have a tipping fee associated with it (e.g. the avoided costs of not sending part of the 145 tons per day that Edmonton sends to Genstar), Table # 12 becomes Table # 13, on page 47.

The avoided cost (or tipping fee) contributed dramatically to the cash flow of the hypothetical project, actually making the gross revenue greater than the debt service costs at the lower interest rates. (Although discussed later, the effects of interest rates on cash flow and project

Table # 12
Revenue from Heat
Effect of the Elimination of Tipping Fee Revenue
Debt Service
60 Ton/Day Facility

Interest rate		9.0%	10.0%	11.0%	12.0%
Incinerator					
Cost/ton	$39,000	$210,600	$234,000	$257,400	$280,800
Steam Boiler					
Cost/ton	$34,000	$183,600	$204,000	$224,400	$244,800
Total					
Cost/ton	$73,000	$394,200	$438,000	$481,800	$525,600
Annual Revenue (Current Energy Cost; No Tipping Fee)					
Steam Value					
per day	$967.91	$353,287	$353,287	$353,287	$353,287
Tipping					
Fee/ton	$0.00	$0	$0	$0	$0
		$353,287	$353,287	$353,287	$353,287
Revenue less					
Debt Service		($40,913)	($84,713)	($128,513)	($172,313)

Table # 13
Revenue from Heat
Effect of the Addition of Tipping Fee Revenue
Debt Service
60 Ton/Day Facility

Interest rate		9.0%	10.0%	11.0%	12.0%
Incinerator					
Cost/ton	$39,000	$210,600	$234,000	$257,400	$280,800
Steam Boiler					
Cost/ton	$34,000	$183,600	$204,000	$224,400	$244,800
Total					
Cost/ton	$73,000	$394,200	$438,000	$481,800	$525,600
Annual Revenue (Current Energy Cost; No Tipping Fee)					
Steam Value					
per day	$967.91	$353,287	$353,287	$353,287	$353,287
Tipping					
Fee/ton	$5.33	$116,727	$116,727	$116,727	$116,727
		$470,014	$470,014	$470,014	$470,014
Revenue less					
Debt Service		$75,814	$32,014	($11,786)	($55,586)

viability is shown vividly in this example.)

It is apparent that each project must have either a genuine tipping fee from an external source, or a direct avoided cost.

9.5 SENSITIVITY TO INTEREST RATES

The interest rate has varied greatly in the past 10 years, rising to historical highs in the early 1980's. At the time of writing, however, the prevailing rate was relatively low, in the 9 % range. Table # 12, on page 46, and Table # 13, on page 47, show very pointedly how much effect even a one percentage point change in the interest rate has on the net cash position before operating costs are included. While the tables are for a 60 ton per day facility, a 100 ton per day table would show the same trends. Interest rates, and their relationship to varying energy costs will be discussed, and presented in graph form, in Section 9.6.

9.6 SENSITIVITY TO ENERGY PRICES

At the time of writing, not only are energy prices very low relative to their peak, but also the prices for energy in Alberta are lower than nearly any other jurisdiction in North America. These facts alone may make one question the value of recovering energy from refuse incineration in Alberta. However, as was demonstrated in Section 8.3, a net cost per ton for refuse disposal can be shown to be around $21.87 which must be evaluated against alternative disposal methods. Of course, the waste recurs without depleting a natural resource.

Using the energy values per day as derived in Appendix D, by varying the price of the two theoretical values for each form of energy in increments of 10 % from -20 % to +30 %, Tables # 14 and # 15, on pages 49 and 50, show daily revenues from each incinerator capacity.

Again using Table # 12, on page 46, as a base, and the natural gas equivalent values from varying energy prices (-20 % to +30 %), one can calculate Tables # 16 and # 17, on pages 52 and 53 for various energy price changes.

The final row of figures, Revenue less Debt Service, from Tables # 12, # 16, and # 17, on pages 46, 52, and 53, plus figures generated in an identical fashion for energy variations of -10 %, +10 %, and +20 %, but not shown here, are contained in Table # 18, on page 54.

When one plots the data in Table # 18, a family of straight line curves, as shown on Graph # 2, on page 55, shows the

Table # 14

Daily Revenues for Varying Energy Prices

Waste Capacity Tons/Day	-20 %	-10 %	Steam Equivalent as Heat Current Price per Gj.	+10 %	+20 %	+30 %
	$2.03	$2.29	$2.54	$2.79	$3.05	$3.30
10	$129.05	$145.19	$161.32	$177.45	$193.58	$209.71
15	$193.58	$217.78	$241.98	$266.17	$290.37	$314.57
20	$258.11	$290.37	$322.64	$354.90	$387.16	$419.43
25	$322.64	$362.97	$403.29	$443.62	$483.95	$524.28
30	$387.16	$435.56	$483.95	$532.35	$580.74	$629.14
35	$451.69	$508.15	$564.61	$621.07	$677.54	$734.00
40	$516.22	$580.74	$645.27	$709.80	$774.33	$838.85
45	$580.74	$653.34	$725.93	$798.52	$871.12	$943.71
50	$645.27	$725.93	$806.59	$887.25	$967.91	$1,048.57
60	$774.33	$871.12	$967.91	$1,064.70	$1,161.49	$1,258.28
70	$903.38	$1,016.30	$1,129.23	$1,242.15	$1,355.07	$1,467.99
80	$1,032.43	$1,161.49	$1,290.54	$1,419.60	$1,548.65	$1,677.71
90	$1,161.49	$1,306.68	$1,451.86	$1,597.05	$1,742.23	$1,887.42
100	$1,290.54	$1,451.86	$1,613.18	$1,774.50	$1,935.82	$2,097.13

Table # 15

Daily Revenues for Varying Energy Prices

Electricity Equivalent from Steam

Waste Capacity Tons/Day	-20 % $0.0280	-10 % $0.0315	Current Price per Kwh $0.0350	+10 % $0.0385	+20 % $0.0420	+30 % $0.0455
10	$111.15	$125.05	$138.94	$152.84	$166.73	$180.63
15	$166.73	$187.57	$208.42	$229.26	$250.10	$270.94
20	$222.31	$250.10	$277.89	$305.68	$333.46	$361.25
25	$277.89	$312.62	$347.36	$382.09	$416.83	$451.57
30	$333.46	$375.15	$416.83	$458.51	$500.20	$541.88
35	$389.04	$437.67	$486.30	$534.93	$583.56	$632.19
40	$444.62	$500.20	$555.77	$611.35	$666.93	$722.51
45	$500.20	$562.72	$625.25	$687.77	$750.29	$812.82
50	$555.77	$625.25	$694.72	$764.19	$833.66	$903.13
60	$666.93	$750.29	$833.66	$917.03	$1,000.39	$1,083.76
70	$778.08	$875.34	$972.60	$1,069.86	$1,167.12	$1,264.39
80	$889.24	$1,000.39	$1,111.55	$1,222.70	$1,333.86	$1,445.01
90	$1,000.39	$1,125.44	$1,250.49	$1,375.54	$1,500.59	$1,625.64
100	$1,111.55	$1,250.49	$1,389.43	$1,528.38	$1,667.32	$1,806.26

effect of varying interest rates and varying energy prices.

For example, at a current interest of 9 %, if the price of energy should rise by approximately 11 % from its present retail value of $2.54 per gigajoule for large commercial customers, the resulting revenue could just service the capital debt structure. On the other hand, a rise of only one percentage point in the interest rate from the current rate would necessitate an energy price rise of about 24 % from the present level in order for the capital debt to be serviced by the energy revenue.

The eventuality of energy costs increasing in Alberta may be closer at hand than one might first imagine. Currently, natural gas users in the province have a subsidy from the provincial government to the amount of $0.595 per gigajoule. Therefore, removal of this Alberta Natural Gas Price Protection Plan would result in an immediate increase in the cost of heat of over 23 %. This plan is due for review by the provincial government in 1987.

Table # 16
Net Revenue Before Operating Costs
Effect of 20 % Decrease in Energy Price
Debt Service
60 Ton/Day Facility

Interest rate		9.0%	10.0%	11.0%	12.0%
Incinerator					
Cost/ton	$39,000	$210,600	$234,000	$257,400	$280,800
Steam Boiler					
Cost/ton	$34,000	$183,600	$204,000	$224,400	$244,800
Total					
Cost/ton	$73,000	$394,200	$438,000	$481,800	$525,600
Annual Revenue (20 % decrease; No Tipping Fee)					
Steam Value					
per day	$774.33	$282,630	$282,630	$282,630	$282,630
Tipping					
Fee/ton	$0.00	$0	$0	$0	$0
		$282,630	$282,630	$282,630	$282,630
Revenue less					
Debt Service		($111,570)	($155,370)	($199,170)	($242,970)

Table # 17
Net Revenue Before Operating Costs
Effect of 30 % Increase in Energy Price
Debt Service

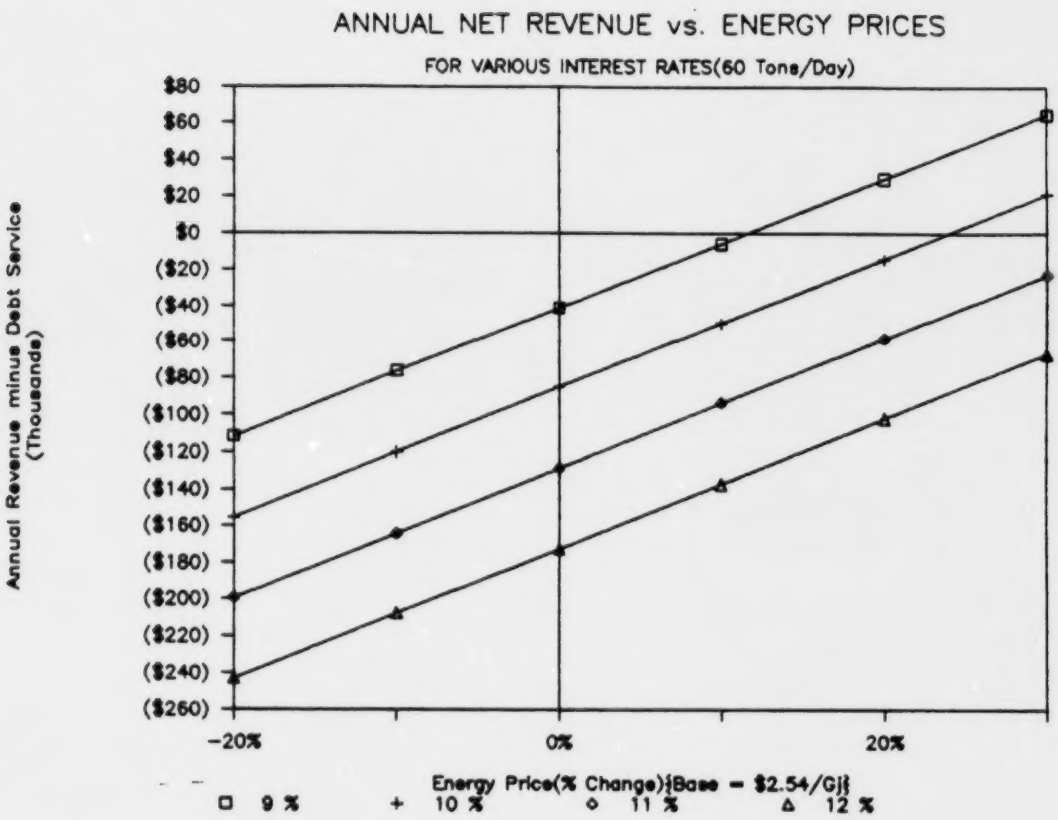
60 Ton/Day Facility

Interest rate		9.0%	10.0%	11.0%	12.0%
Incinerator					
Cost/ton	$39,000	$210,600	$234,000	$257,400	$280,800
Steam Boiler					
Cost/ton	$34,000	$183,600	$204,000	$224,400	$244,800
Total					
Cost/ton	$73,000	$394,200	$438,000	$481,800	$525,600
Annual Revenue (30 % increase; No Tipping Fee)					
Steam Value					
per day	$1,258.28	$459,272	$459,272	$459,272	$459,272
Tipping					
Fee/ton	$0.00	$0	$0	$0	$0
		$459,272	$459,272	$459,272	$459,272
Revenue less					
Debt Service		$65,072	$21,272	($22,528)	($66,328)

Table # 18
Annual Revenue Less Debt Service vs. Energy Price Variations
Tipping Fees Eliminated
60 Ton/Day Facility

Interest	9.0%	10.0%	11.0%	12.0%
Energy Price				
-20%	($111,570)	($155,370)	($199,170)	($242,970)
-10%	($76,241)	($120,041)	($163,841)	($207,641)
0%	($40,913)	($84,713)	($128,513)	($172,313)
10%	($5,585)	($49,385)	($93,185)	($136,985)
20%	$29,744	($14,056)	($57,856)	($101,656)
30%	$65,072	$21,272	($22,528)	($66,328)

Graph # 2


ANNUAL NET REVENUE vs. ENERGY PRICES
FOR VARIOUS INTEREST RATES(60 Tons/Day)
Annual Revenue minus Debt Service (Thousands)
$80
$60
$40
$20
$0
($20)
($40)
($60)
($80)
($100)
($120)
($140)
($160)
($180)
($200)
($220)
($240)
($260)
-20%
0%
20%
Energy Price(% Change){Base = $2.54/GJ}
9 %
10 %
11 %
12 %

10.0 CONCLUSIONS

1. The primary purpose of waste incineration is to facilitate waste disposal by means of volume reduction. That garbage can be disposed of by incineration is not in question; this technology has existed for over 50 years and is continually being refined. There are many private companies manufacturing the system components, thereby indicating that the concept is commercially viable.

2. Environmental effects can be kept within existing operational standards as defined by Alberta Environment. Indeed, that commercial manufacturers continue to market their products in spite of increasingly more stringent standards throughout North America is a testimony that environmental concerns about garbage incineration can be satisfied.

3. Energy can be recovered from the incinerated garbage. Generating hot water or steam which is used as a source of heat is the most common method. Energy in the form of electricity from small incinerators does not appear to be common.

4. The market for recaptured energy is questionable because the recaptured energy costs too much. However, reasonable models can be constructed using theoretically recoverable heat quantities from commercially available waste-to-energy systems. Approximate capital and operating costs can be estimated based on current data from existing North American systems, thereby giving current economic operating expectations for various configurations.

5. The concept of district heating for small towns, or subdivisions of large cities, is not practical for Alberta at this time. The best prospect is for the integration of an energy recovery incinerator with one large commercial/industrial user of the energy. Essential to the success of any integrated project is the contracting of not only the energy production to the chosen customer, but also the assurance that the supply of refuse for its design capacity is delivered daily.

6. The addition of energy recovery equipment can be shown to reduce the net cost per ton of waste disposal, if there is a customer for the energy. Prevailing operating costs, interest rates, and energy costs severely affect the net costs.

7. To build an incineration facility without energy recovery can be justified only if:
   a. its estimated waste disposal cost per ton is approximately equal to that of other methods;
   b. there are constraints on other methods of disposal which makes them unacceptable at any price, and/or;
   c. there is the potential to retrofit the incinerator when economic conditions indicate that the sale of heat and/or electricity reduce the net per ton cost of waste incineration.

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APPENDIX A

QUESTIONNAIRE

APPENDIX A

BJORN HOLDINGS LTD.
4707 - 141 St.
Edmonton, Alberta T6H 3Z9 Canada

16 April 1986

I am writing to you in order to enlist your help in obtaining current, state-of-the-art operating information on existing waste incineration and waste to energy facilities.

I am an independent consultant presently conducting a study on behalf of the Province of Alberta Department of Housing on the feasibility of incinerating domestic and commercial refuse coupled with a heat recovery and distribution system for single and multiple family dwellings, small shopping centers, schools, and/or sports complexes here. Generally, my study is concerned with facilities that incinerate up to 100 tons of refuse per day.

Accordingly, I have drafted the enclosed questionnaire which, when completed, will contain data relevant to my study. Your cooperation in filling it out will be greatly appreciated. If no data are available regarding a particular question, please so state.

Questions regarding my involvement in this study may be directed to:

Mr. Walter Cool, P.Eng.
Research Project Manager
Alberta Department of Housing
10050 - 112 St.
Edmonton, Alberta T5K 2J1

A self-addressed stamped envelope is enclosed for your convenience.

Thank you.

Sincerely yours,

Nelson M. Cochran

APPENDIX A

Questionnaire
CONTROLLED AIR INCINERATION FACILITIES

Facility name and address: Date built_____

Area (acres) _____

Number of people serviced by facility_____

Capacity (tons per hour)_____

Hours per day of operation_____

Average Btu content of refuse_____

Average moisture content of refuse_____

Pre-prossessing of refuge
(metal or glass extraction, grinding, etc.)

Results of particulate and gaseous (HCl & SO)emission tests
_____

COSTS
Initial cost of:
Loading and/or feeding equipment_____

Incineration equipment_____

Environmental controls (scrubbers, etc.)_____

Building and office_____

Land_____

Scale_____

Operating costs:
Utilities (per year)
1. natural gas or oil_____
2. water_____
3. power_____

Personnel
1. administrative (number and cost)_____
2. operating (number and cost)_____

Other fuel costs._____

Property taxes_____
Insurance_____
Maintenance_____

REVENUES
From heat or power sold (or fuel saved)_____

From salvaged material_____

From taxes (per capita)_____

Other sources (?)_____

COMMENTS:

APPENDIX A

BJORN HOLDINGS LTD.
4707 - 141 St.
Edmonton, Alberta T6H 3Z9
CANADA

12 June 1986

Having obtained your name, and a brief description of your facility, from a Resource Recovery Activities Report, compiled by staff from the U.S. Conference of Mayors and the magazine, Waste Age, and published in the November, 1985 issue of that magazine, I recently sent you a copy of the enclosed questionnaire, along with a self-addressed envelope.

It would be extremely helpful to me in completing the study I am doing for the Government of Alberta if you would answer as many of the questions as possible and return the form to me in the enclosed envelope.

Thank you for your cooperation.

Sincerely yours,

Nelson M. Cochran

APPENDIX A QUESTIONNAIRE RESULTS

FACILITY LOCATION	DATE BUILT	POPULATION SERVICED	CAPACITY Tons/day	PRE-PROCESSING	FEED EQUIPMENT	CAPITAL INCINERATOR	COSTS CONTROLS (SCRUBBER)	OFFICE & BUILDING	LAND	SCALES
CANADA (Dollar figures in Canadian Dollars)										
CHARLOTTETOWN, P.E.I.	1983	45,000 & Tourists	108	None		$8,000,000 (total)	(None)			(None)
DUNCAN, B.C.	1979	29,200	42	Extract large metal						
LADYSMITH, B.C.	1980	1?,000	12	Extract large metal						
LAKE COWICHAN, B.C.	1975	6,200	10	Extract large metal						
TUMBLER RIDGE, B.C.	1986	6,000	12	Extract	$25,000	$311,000	nil	$105,000	nil	nil
UNITED STATES (Dollar figures in U.S. Dollars)										
REDSTONE ARSENAL, ALABAMA	1983	25,000	50	Extract large items		$3,000,000 total				
SITKA, ALASKA	1985	8,000	20	None		$2,000,000 total		$1,500,000		
OSCEOLA, ARKANSAS	1979	15,000	50	Extract large metal	$22,000		$1,200,000 total			
WINDHAM, CONNECTICUT	1981	70,000	120			$2,300,000	Bag House	$900,000	$0	$32,000
COLLEGEVILLE, MINNESOTA	1981	75,000	45	None		$2,500,000 (total)				
RED WING, MINNESOTA	1982	26,000	72	None	$50,000	$1,305,496	$700,000	$1,101,309		
FORT LEONARD WOOD, MISSOURI	1982	27,000	75	None		$3,000,000	(total)			
LIVINGSTON, MONTANA	1981	?	70	Extract large metal		$2,600,000	(total)			
DURHAM, NEW HAMPSHIRE	1980	5,000	36	None	$38,000	$2,300,000	None	$1,000,000	$0	(In bldg. & office)
LEWISBURG, TENNESSEE	1980	?	60	None	$25,000	$385,199	$182,762	$1,168,143	$70,476	(With equipment)
CLEBURNE, TEXAS	1986	20,000	114	?		$5,500,000	(total)			
GALAX, VIRGINIA	1985	?,000	55	None	$1,382,950	(total)		$460,04?	$26,000	

APPENDIX A QUESTIONNAIRE RESULTS (Continued)

FACILITY LOCATION	TOTAL CAPITAL COST	COST PER TON-DAY	OPERATING COSTS NATURAL GAS OR OIL	WATER	POWER	PERSONNEL COSTS ADMIN.	OPERATING	TAXES	OTHER COSTS INSURANCE	MAINTENANCE
CANADA (Dollar figures in Canadian Dollars)										
CHARLOTTETOWN, P.E.I.	$8,000,000	$74,074	$2,700	$2,800	$150,000		$370,000	$70,000		$240,000
DUNCAN, B.C.	$0	$0	$15,865	nil	$10,982	$17,483	$232,015			
LADYSMITH, B.C.	$0	$0	$5,127	NIL	$3,281	$11,700	$98,122			
LAKE COWICHAN, B.C.	$0	$0	$2,908	NIL	$4,082	$10,350	$76,992			
TUMBLER RIDGE, B.C.	$441,000	$36,750	$10,000	$2,000	$4,500		$35,000	NIL	$1,000	$5,000
UNITED STATES (Dollar figures in U.S. Dollars)										
REDSTONE ARSENAL, ALABAMA	$3,000,000	$60,000			$60,000					
SITKA, ALASKA	$3,500,000	$175,000	$44,000 total			$200,000		NIL	$3,000	$23,000
OSCEOLA, ARKANSAS	$1,222,000	$24,440	$1,000			$28,600	$114,400			$14,400
WINDHAM, CONNECTICUT	$3,232,000	$26,933		$48,000	$80,000	$70,000	$300,000		$38,000	$125,000
COLLEGEVILLE, MINNESOTA	$2,500,000	$55,556	$0	$0	$25,756		$102,757		$3,000	$60,000
RED WING, MINNESOTA	$3,156,805	$43,845	$40,000 (gas & power)			$308,000	$153,000		$4,000	
FORT LEONARD WOOD, MISSOURI	$3,000,000	$40,000								
LIVINGSTON, MONTANA	$2,600,000	$37,143	$20,000	$4,320	$14,400					$300,000
DURHAM, NEW HAMPSHIRE	$3,330,000	$92,722	$0	$1,000	$80,000				$38,000	$250,000
LEWISBURG, TENNESSEE	$1,831,580	$30,526	$0	$10,800	$110,000		$109,000			$62,000
CLEBURNE, TEXAS	$5,500,000	$48,246								
GALAX, VIRGINIA	$1,868,992	$33,982	$18,000	$5,000	$30,000		$91,000			

APPENDIX A QUESTIONNAIRE RESULTS (Continued)

FACILITY LOCATION	TOTAL OPERATING COSTS	OPERATING COSTS PER TON	REVENUE ENERGY SOLD	REVENUE MATERIAL SALVAGED	REVENUE TAXES	REVENUE DUMPING CHARGE	TOTAL REVENUE	COMMENTS
CANADA (Dollar figures in Canadian Dollars)								
CHARLOTTETOWN, P.E.I.	$835,500	$21.19	$957,000	$2,500	$295,000		$1,254,500	
DUNCAN, B.C.	$276,345	$16.11	$0	$0	$200,312	$300,000	$500,312	
LADYSMITH, B.C.	$118,230	$26.99	$0	$0	$148,070	$66,000	$214,070	
LAKE COWICHAN, B.C.	$94,337	$25.85	$0	$0	$209,994	NIL	$209,994	
TUMBLER RIDGE, B.C.	$57,500	$13.13	$0	$0	$0		$0	
UNITED STATES (Dollar figures in U.S. Dollars)								
REDSTONE ARSENAL, ALABAMA	$60,000	$3.29					$0	no household refuse burned; only paper waste
SITKA, ALASKA	$270,000	$36.99	$100,000	$0	$0	$250,000 collection	$350,000	
OSCEOLA, ARKANSAS	$158,400	$8.68	$240,000	$0	$0	$21,600 tipping	$261,600	
WINDHAM, CONNECTICUT	$661,000	$15.09				$1,200,000 tipping	$1,200,000	
COLLEGEVILLE, MINNESOTA	$191,513	$11.66	$180,676			$81,762	$262,438	
RED WING, MINNESOTA	$505,000	$19.22	$286,000		$121,000		$407,000	
FORT LEONARD WOOD, MISSOURI	$0	$0.00					$0	Military installation; no information given
LIVINGSTON, MONTANA	$338,720	$13.26	$390,000	$0		$638,750 tipping	$1,028,750	
DURHAM, NEW HAMPSHIRE	$369,000	$28.08	$500,000	$0		$610,000 tipping	$1,110,000	
LEWISBURG, TENNESSEE	$291,800	$13.32	$60,000	?	?	?	$60,000	
CLEBURNE, TEXAS	$0	$0.00					$0	Just completed; No operating info.
GALAX, VIRGINIA	$144,000	$7.17	$260,000				$260,000	Just completed; Data are from budget.

APPENDIX B

EDMONTON JOURNAL EDITORIAL

APPENDIX B

A burning issue

Incineration is touted by some Edmontonians as an attractive alternative to establishing another huge landfill site within city limits. But a recent Ontario study raises serious questions about the long-term environmental impact of burning huge quantities of trash.

The report by Kate Davies, a biochemist for the Toronto public health board, found low levels of toxic chemicals — including dioxins, DDT, pesticides and PCBs — in food produced in southern Ontario.

Pollution Probe researchers say garbage incineration is the major source of dioxins in the environment and blame three outdated municipal incinerators — one in Hamilton and two in Toronto — for most of the trouble.

The dioxins are released when waste is burned at temperatures too low to destroy the toxic chemicals. There are 75 different kinds of dioxins and scientists believe long-term exposure to the chemicals may be linked to chronic health problems, including cancer.

New high-temperature incinerators equipped with sophisticated gas scrubbers are said by some experts to be environmentally sound if maintained and operated properly. But they are expensive.

City of Edmonton officials say it would cost $95 million to build such an incinerator. When operating costs are added, the average taxpayer is looking at a $70 annual levy. By comparison, a landfill site would cost an average $8.71 per year. A landfill site would still be necessary with an incinerator to dispose of the ashes and act as a backup.

Landfill sites do present environmental problems — noise, smell and the potential leaching of chemicals into the water system. But the threat posed by improper incineration is greater, especially for people living downwind of the city.

Edmontonians must dispose of their garbage in a responsible manner. And that rules out incineration.

Editorial from The Edmonton Journal, 5 June 1986

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APPENDIX C

INCINERATOR COMPONENTS

APPENDIX C

Incinerator Components With Energy Recovery

Mechanical Loader with Fire Control and Side Panels (Side Loading)
Primary Chamber with High temperature Protection
Brich Hearth - Lower 150° Segment
Ash Ejection and Internal Transfer Ram
Wet Ash Conveyor with Hydraulic Motor
Cooling Skid for Water Cooling Face Plate of the Transfer Ram, Ram Air Tubes and Ash Ejector includes Cooling Skid and Air to Water Heat Exchanger
Hot Gas Breeching to Boiler
Firetube Boiler - 150 PSI Design Pressure
Energy Ducting
ID Fan with Manual Damper
Incinerator and Energy Recovery Solid State Controls
Stack (3 Sections - Incineration Only
32' Freestanding Stack (Energy Systems)
Upper Chamber Air Shroud
Upper Chamber Inspection Door/Blower Platform
Lower Chamber Walk-in Door/Inspection Door Platform
360° Upper Chamber Brick Lining
Loading Bridge and Corner Guards
IRI Controls - U.V. Sensors - Natural Gas Burners
Remote Control Box
Remote Control Actuator
Solid State Control System with Programmable Controller, Time/Counter, Portable Computer with 2 disc drives and 640K memory and 300 Baud Modem

Options for Continuous Duty Systems

Over-the-End Loader
Cart Dumping Loader
Lower Chamber Shroud
Burner Options
Liquid Waste Adapter
Infectious Waste Controls
Ash Conveyor Chain Spray
High Output Blowers
Inspection Ports on Stack
Blower Filters
Free Standing Stack
U.L. Approved Stack
Spark Screen

Source: A U.S. equipment manufacturer.

APPENDIX C

Incinerator Components Without Energy Recovery

Mechanical Loader with Fire Control and Side Panels (Side Loading)
Primary Chamber with High temperature Protection
Brich Hearth - Lower 150° Segment
Ash Ejection and Internal Transfer Ram
Wet Ash Conveyor with Hydraulic Motor
Cooling Skid for Water Cooling Face Plate of the Transfer Ram, Ram Air Tubes and Ash Ejector includes Cooling Skid and Air to Water Heat Exchanger
Stack (3 Sections)
Upper Chamber Air Shroud
Upper Chamber Inspection Door/Blower Platform
Lower Chamber Walk-in Door/Inspection Door Platform
360° Upper Chamber Brick Lining
Loading Bridge and Corner Guards
IRI Controls - U.V. Sensors - Natural Gas Burners
Remote Control Box
Remote Control Actuator
Solid State Control System with Programmable Controller, Time/Counter, Portable Computer with 2 disc drives and 640K memory and 300 Baud Modem

Options for Continuous Duty Systems

Over-the-End Loader
Cart Dumping Loader
Lower Chamber Shroud
Burner Options
Liquid Waste Adapter
Infectious Waste Controls
Ash Conveyor Chain Spray
High Output Blowers
Inspection Ports on Stack
Blower Filters
Free Standing Stack
U.L. Approved Stack
Spark Screen

Source: A U.S. equipment manufacturer.

APPENDIX D

THEORETICAL ENERGY GENERATION FROM THE INCINERATION OF WASTE

APPENDIX D
THEORETICAL ENERGY GENERATION FROM THE INCINERATION OF WASTE

WASTE CAPACITY TONS/DAY	4300 Btu/lb Refuse BTU CONTENT	BOILER 70 %	GJOULE	ENERGY AS STEAM FOR HEAT VALUE $/GJOULE $2.54	STEAM 30 %	THERMAL EXPANSION 12 %	TURBINE EFFICIENCY WITH STEAM 25 %	12 %	ENERGY AS ELECTRICITY Btu/3412 KW STEAM	Btu/KW 12 %	VALUE OF KWh KWh x $.035/KWh STEAM	12 %
10	86,000,000	60,200,000	63.51	$161.32	18,060,000	7,224,000	13,545,000	5,418,000	3,970	1,588	$138.94	$55.58
15	129,000,000	90,300,000	95.27	$241.98	27,090,000	10,836,000	20,317,500	8,127,000	5,955	2,382	$208.42	$83.37
20	172,000,000	120,400,000	127.02	$322.64	36,120,000	14,448,000	27,090,000	10,836,000	7,940	3,176	$277.89	$111.15
25	215,000,000	150,500,000	158.78	$403.29	45,150,000	18,060,000	33,862,500	13,545,000	9,925	3,970	$347.36	$138.94
30	258,000,000	180,600,000	190.53	$483.95	54,180,000	21,672,000	40,635,000	16,254,000	11,909	4,764	$416.83	$166.73
35	301,000,000	210,700,000	222.29	$564.61	63,210,000	25,284,000	47,407,500	18,963,000	13,894	5,558	$486.30	$194.52
40	344,000,000	240,800,000	254.04	$645.27	72,240,000	28,896,000	54,180,000	21,672,000	15,879	6,352	$555.77	$222.31
45	387,000,000	270,900,000	285.80	$725.93	81,270,000	32,508,000	60,952,500	24,381,000	17,864	7,146	$625.25	$250.10
50	430,000,000	301,000,000	317.56	$806.59	90,300,000	36,120,000	67,725,000	27,090,000	19,849	7,940	$694.72	$277.89
60	516,000,000	361,200,000	381.07	$967.91	108,360,000	43,344,000	81,270,000	32,508,000	23,819	9,528	$833.66	$333.46
70	602,000,000	421,400,000	444.58	$1,129.23	126,420,000	50,568,000	94,815,000	37,926,000	27,789	11,115	$972.60	$389.04
80	688,000,000	481,600,000	508.09	$1,290.54	144,480,000	57,792,000	108,360,000	43,344,000	31,758	12,703	$1,111.55	$444.62
90	774,000,000	541,800,000	571.60	$1,451.86	162,540,000	65,016,000	121,905,000	48,762,000	35,728	14,291	$1,250.49	$500.20
100	860,000,000	602,000,000	635.11	$1,613.18	180,600,000	72,240,000	135,450,000	54,180,000	39,698	15,879	$1,389.43	$555.77

APPENDIX E

WASTE-TO-ENERGY: ANATOMY OF A FAILURE

APPENDIX E

Resource Recovery

Waste-To-Energy: Anatomy Of A Failure

Poor planning and mechanical problems were the downfall of California's first waste-to-energy facility at Lassen Community College.

By **Thomas C. Reilly**
and **Linda Morse**

CALIFORNIA'S FIRST waste-to-energy project was a flop. A 96-ton-per-day waste-to-energy plant developed at Lassen Community College, 250 miles northeast of San Francisco, operated only six months (from December 1984 to May 1985) before it shutdown. The college has filed bankruptcy as a direct result of the project.

Brown, Vence & Associates, an energy and environmental engineers group in San Francisco, recently investigated the project's failure. Their results showed that the project failed for reasons other than waste-to-energy technology nonperformance.

The Lassen Community College District covers most of Lassen County and a small portion of Modoc County in California. The District governs Lassen Community College, which is near Susanville, close to the Nevada border.

The waste-to-energy project was conceived in the late 1970s by the District superintendent who has since resigned. After discussing the escalating costs of electricity and space heating, the College's Governing Board accepted a proposal for a municipal solid waste-fueled congregation project for reducing the college's rising energy costs. The concept was expanded to include a student training facility. On November 1, 1982, $7.15 million worth of Certificates of Participation (see Table I.) were issued to finance the project which was rated BBB–. The District secured the Certificates.

This choice of financing was unusual for the college. Typically, capital projects are funded by District revenue or by a bond issue. Certificate-backed construction projects must be reviewed by a building committee of the California Community Colleges at the state level, but the District administration apparently never submitted this project for approval.

The facility, built on five acres of college-owned land adjacent to the campus, consists of a waste-fired cogeneration plant and a training facility. (See Table II.) The project was designed to satisfy the college's steam heat requirement, to sell excess thermal energy to industrial users, to sell electricity to the college (about 2.8 million kWh per year), and to sell the remaining amount to Pacific Gas and Electric (PG&E), the local utility (about 6.3 million kWh per year).

The plant is designed around a Brunn & Sorensen Type W-400 incinerator system (one unit). The system uses a refractory-wall furnace with a 30-degree inclined, articulated grate. Fuel is fed to the furnace feed hopper by the overhead crane and grapple system. A hydraulic ram at the base of the fuel feed chute pushes fuel material onto the grate. No auxiliary fuel burners are installed in the furnace. Ash drops from the end of the grate into a refractory lined chute. The ash is cooled by water sprays, and is pushed onto a conveyer system by hydraulic ram.

Hot combustion gases pass from the furnace through a refactory lined, horizontal breech to a Bronswerk Utrecht watertube, waste heat boiler. Steam from the boiler flows to a Terry two-stage steam turbine connected to a generator. Steam extracted at the end of the turbine's first stage passes through a tube-and-shell heat exchanger to heat water for the College's hot water system. The condensate from the heat exchanger returns to the condenser. Steam not extracted at the first stage passes through the turbine second stage and is condensed.

Air pollution equipment installed at the plant consists of a spray chamber and baghouse. The 3-compartment baghouse uses pulse jet cleaning and teflon-coated fiberglass bags. Fly ash from the baghouse and spray chamber bottom residue are transferred by a common screw conveyor system and emptied into an outdoor storage bin.

Analyzing The Plans

The Lassen's rural location provided access to an abundant supply of wood waste, but relatively small quantities of locally generated municipal solid waste (MSW). The developer, Lahontan, and the college originally planned a fuel supply mix of MSW and wood waste.

The plan was to use up to 50 percent wood waste for the facility's fuel supply. However, during the plant's two-year design and construction phase, three wood-fired power plant projects in Burney, Westwood and Susanville began operations. These facilities used much of the local wood waste supplies that Lassen had planned to use. In addition, the project staff felt that the proportion of wood waste to MSW would have to be much lower to avoid combustion temperatures too high for the Brunn & Sorensen refractory-lined furnaces, which were designed to handle relatively low Btu (4,300-4,500 Btu/lb) fuels.

Even after this plan was cancelled and the facility was completed, an adequate MSW supply was not secured. In early 1985, Lassen made an agreement with the local private disposal company to receive MSW supplies from three local sources and from Reno, Nev., (about a 90-mile one-way haul). However, the agreement did not guarantee a minimum supply, it only provided the first right to the MSW in Lassen and Shasta Counties. The Reno agreement provided a guaranteed supply of 250 tons per week, but this was little more than a third of the full requirement.

No waste composition data were available for the received waste supplies. Limited sampling of the waste was done during actual operation; more were planned.

Unlike most waste-to-energy plants, the Lassen project received no revenue from tipping fees for its MSW fuel supply. Lassen either had to pay for the waste, receive it at no cost or pay transportation cost. For the waste hauled from Reno, the college paid $10 per ton for 66 tons per day.

Prior to facility operation, state regulatory agencies, as well as plant managers, had assumed that fly ash from the facility would be hazardous and the bottom ash would be non-hazardous.

Sampling of the fly ash, bottom ash and combined ash was done during facility operation as part of a state-funded testing and monitoring program. As expected, fly ash was found to be hazardous with lead, cadmium, copper, zinc, mercury and antimony exceeding acceptable levels. Unexpectedly, the majority of the bottom ash samples also tested hazardous, with high levels of lead. In addition, combined samples of fly and bottom ash also tested hazardous with unacceptable levels of lead and cadmium.

No definitive explanation of the lead content in the bottom ash has been found. Speculation arose that car batteries and electronic components in the waste supply may have caused the high lead values. Further testing, planned during plant operation to correlate waste composition, was thwarted by plant shutdown.

Because the ash testing results are suspect due to a possible contaminated waste supply, the State Department of Health Services has not changed its opinion on the hazardous nature of ash; fly ash is still considered hazardous; bottom ash, non hazardous; and combined ash, unresolved.

Originally, Lassen had proposed a disposal site on campus, but the local water quality agency vetoed this idea. Then, in the spring of 1985 (after the facility began operating), a permit application was submitted to use a separate disposal cell at a Lassen County landfill. The permit was denied.

Currently, the fly ash and bottom ash are stored under a temporary waiver on campus property and on adjacent Bureau of Land Management property.

The Lassen facility has not operated since mid-May 1985. Several engineering reviewers (after the plant ceased operation) and the plant operator agree that the turbine/generator was the major cause of plant failure. However, there is no clear consensus on the cause of the turbine/generator breakdown.

During operation of the facility, the turbine/generator experienced damage from excessive vibration. Opinions differ as to whether the vibration was created by inadequate turbine/generator mounting or whether mechanical problems with the turbine itself caused the problem. When the facility was shut down, it was found that three turbine blades were missing; only one was recovered.

In general, engineering reviewers felt that the overall plant was well constructed and engineered, but that the systems engineering and auxiliary equipment selection were inadequate. No problems were encountered during operation with the Bruun & Sorensen furnace and boiler technology. In addition, the nature of the MSW fuel did not directly cause operating problems.

Several other minor problems also were found during and after operation. Plant operators and engineering reviewers agree that these problems are all solvable and should not impede future operation. The problems include:

- Inadequate feedwater pumps causing inconsistent delivery of feedwater.
- Silica build-up in boiler feedwater due to lack of demineralization system, forcing plant to operate at 20 percent blowdown rate.
- Inadequate bottom ash removal system including unacceptable external handling.
- Improper fly-ash collection system that created bridging.
- Need for fourth baghouse module to ensure efficient cleaning while on-line.

The Lassen project, as originally designed, would receive revenue from electrical sales to PG & E, and thermal energy sales to PG & E, and thermal energy sales to Lassen. During actual

Table I. Allocation of Project Funds

Project cost		$4,609,033
Contingency		316,930
Reimbursable project costs to district		250,000
	Total Project Cost	**$5,175,963**
Less: reinvestment earnings		563,187
	Subtotal	**$4,612,776**
Capitalized interest		1,064,162
Reserve fund		858,312
Costs of issuance		150,000
Certificate discount		464,750
Total Principal Amount of Certificates		**$7,150,000**

Table II. Facility Design

MSW capacity	96 TPD @ 84% projected availability
Boiler output	22,200 lb/hr @ 385 psig, 650°F
Rated capacity	1,500 KW
Net capacity	1,267 KW
Estimated electrical output	9.1 million Kwh per year

Table III. Key Project Participants

Lassen College — Responsible for ownership and operation of the facility and meeting the debt service.

Project Developer — Lahontan, Inc. of Sacramento, Calif. Responsible for managing design and construction of facility.

Waste-to-Energy Technology Vendor — Brunn & Sorensen. Responsible for chute-to-stack design and supply.

Project Designer — Koepf & Lange, Inc., Lafayette, Calif. Responsible for the balance of plant design.

Project Constructor — John F. Otto, Inc. Responsible for project construction.

Investment Banker — Merrill Lynch White Weld Capital Markets Group. Responsible for placement of project financing.

State Agencies — Five state agencies with regulatory, advisory, and funding functions: California Energy Commission (CEC), California Waste Management Board (CWMB), Air Resources Board (ARB), State Water Resources Control Board (SWRCB), and Department of Health Services (DOHS).

operation, the facility fell far short of expectations in electricity sales to PG & E and never sold any thermal energy to the college.

The Lassen project suffered due to two major miscalculations that drastically reduced revenues from electricity sales: a lower energy price for electricity than projected and less generation of electricity from the plant than expected.

The college did not have a signed fixed price power purchase agreement which would have guaranteed energy prices for the project, even though it was available at the time of negotiations with PG&E. Instead, Lassen chose to sign a contract for delivered capacity and energy, in which the prices fluctuate. The contract was signed on October 4, 1984.

The original feasibility study, completed in August 1982, assumed the price for electricity from PG&E in 1985 would be 8.72 cents per kWh. The energy price projections proved to be overly optimistic. The college only received an average of 7.18 cents per kWh during its operation. Prices have since dropped much further, making the revenue prospects for the plant even more grim.

Technical problems prevented the facility from meeting its expected electricity generation. Facility economics were based on the assumption that the plant would operate at a 100 percent capacity during the typical shakedown/start-up period.

For Lassen Community College, the waste-to-energy plant's failure has resulted in negative publicity, possible cutbacks in academic programs and, possibly, a damaged credit history. Apparently, the college is unable to meet any further debt service payments. Furthermore, the top administration is interested in divesting itself of further responsibility and is not interested in operating the facility in the future. The College District filed bankruptcy in March 1986, to stabilize the college's finances.

Several Lessons Learned

Lassen College made vital mistakes that others can learn from. The following are key ingredients to successful project implementation:

- Project risks need to be identified, analyzed and allocated among project participants. The "what ifs" must be scrutinized prior to project implementation.
- Project participants should have adequate finances to cover risks.
- Contracts for water supply and energy must adequately support project financing.
- The waste stream should be monitored to minimize the combustion of incompatable waste. Combustion technology with a proven track record increases the probability of successful plant implementation, but does not guarantee success without equally proven support systems.
- Waste-to-energy project development should be managed by an experienced manager who is surrounded by an experienced staff.
- A shakedown/start-up period must be part of any implementation schedule to detect and correct unforeseen problems. Never project 100 percent plant availability during this period.

The state waste management board recently proposed a state takeover of the facility as a demonstration and testing facility for California. It is too early to predict the outcome of this proposal or to foresee the future of the Lassen facility.

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